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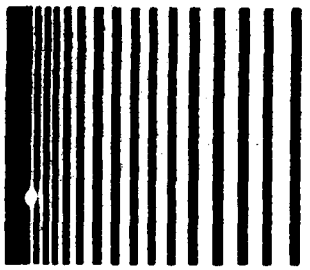

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Dr. R.L. Eshleman
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Suite 206, 101 West 55th Street
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Washington, D.C. 20375-5000
(202) 767-2220

Dr. J. Gordan Showalter
Acting Director

Rudolph H. Volin

Elizabeth A. McLaughlin

Mary K. Gobbett

SVIC NOTES

Structural/Control Interaction - A New Discipline

We are entering a new phase in space exploration where we will need to actively control large flexible structures, such as the space station. This in turn will require both the development and verification of new technologies and extensions in the current fields of structural dynamics and controls.

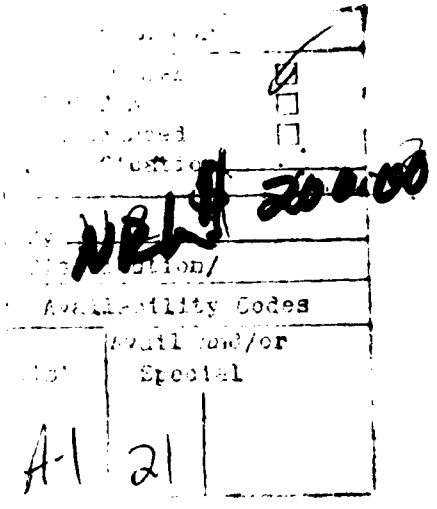
The new large space structures are designed for the zero gravity environment and have unusual characteristics. They have very low natural frequencies, are made up of thousands of rigid elements, have solar arrays and antennas that require active shape control and have control sensors and actuators located throughout the structure.

The modal frequencies of these large structures will be so low that the control frequencies will overlap the structural frequencies causing potential control/structure interaction problems. In the past these problems could be handled by treating the spacecraft as a rigid body then compensating through filtering to eliminate elastic body feed back. The assumption of rigidity is not a reasonable one; elastic body effects must be included in the design of the control system. And, it won't do to simply send the mode shapes, frequencies and damping values from the structures department over to the control systems department. The whole problem must be solved together.

The control engineer and structural dynamicist must become a team and, in essence, create a new discipline, "structural control interaction." The new field can be split into the following discipline areas: 1) analytic modeling and model reduction, 2) system identification, 3) control-law design methodology, 4) integrated structure/control design methodology, 5) sensor and actuator development, 6) ground testing and 7) on-orbit testing.

There still isn't a wildly accepted name for this field of endeavor although cyber-elasticity and servo-elasticity have been suggested. There are a few pioneering individuals from both the structures and controls fields who have learned each other's business because their jobs required it. Also a handful of students have chosen thesis topics in this subject area. This new field is a nice mix of well established technology and new technology such as on-orbit testing. There will be a golden opportunity for those individuals who now choose the fields of cyber- or servo-elasticity.

J.G.S.



EDITORS RATTLE SPACE

THE ROLE OF PERSONAL COMPUTERS IN VIBRATION ANALYSIS AND DESIGN

Each day new applications of the personal computers to problems in shock and vibration engineering and analysis appear. As an illustration, dedicated microprocessors have been used for several years to do fast Fourier transform spectrum analysis. Now the hardware and software to do this task has become available for ordinary personal computers. This not only provides a low cost spectrum analyzer, but also allows multiple uses for the personal computer. Personal computer capabilities continue to increase -- both in speed and storage capacity. Software is available to do engineering computation, design, graphics, and data acquisition, manipulation, analysis, and storage.

The rapid growth of personal computer capabilities has not occurred without problems. These problems relate to the growth of any new technology. In computers, communication, training, application, and coordination of capabilities present problems. Each personal computer has its strengths and weaknesses both in the hardware and the available software. In some cases it would be beneficial to use the computer as a controller. Communications need to be established between the computer and the device under test and/or test instrumentation. Even though some standard means of communication have been established, problems usually occur in achieving this compatibility.

It appears that training and application remain significant problems. Many people first dealing with computers do not have a computer background or awareness. Many of computer operational manuals are difficult for experts to use -- much less a new person in the field. Many are verbose, multipurpose manuals that leave the user confused and discouraged.

One would like to merge the computer capabilities from design to developmental testing. However, operating systems and communications often make this task impossible. Similar to main frame computers, personal computer operating systems are constantly being "upgraded." This often means that old software will not run on new systems.

While the personal computer is providing us with increased capability to solve engineering problems, it will not achieve its full capability until some of the aforementioned problems are dealt with. More effort has to be focused on operations manuals by the computer manufacturers. Standard languages and communications are needed if multitask functions are to become routine. More long range planning on operational systems and software needs to be done so that existing equipment does not become obsolete in months. In all probability the initiative and direction of this work will have to come from the user.

R.L.E.

A REVIEW OF DYNAMIC BEHAVIOR OF STIFFENED PLATES

A. Mukherjee* and M. Mukhopadhyay

Abstract. The paper is a review of analytical and numerical tools for studying dynamic behavior of stiffened plates. The various approaches include orthotropic plate approximation, grillage approximation, and plate and beam idealization.

The hulls decks and superstructures of ships; highway bridges; and launching pedestals for rockets and other structures are examples of stiffened plates subjected to dynamic loads of varying magnitude and complexity. Investigators from different fields have contributed to the diverse literature on stiffened plates.

The dynamic behavior of stiffened plates has been studied for more than 30 years. Various aspects of the problem have been reviewed [1-6], but no comprehensive study of the literature exists.

A plate interwoven with stiffeners renders an exact analytical solution difficult if not impossible. Two earlier methods assumed that the stiffeners were dispersed within the plate; the system was idealized as an orthotropic plate [7-22]. The stiffener system has been approximated as a grid [23-26].

Later solutions considered the plate and the stiffener separately but maintained compatibility between them [27-85]. The advent of electronic digital computers led to the development of such numerical techniques as the finite difference and finite element methods. Recent advancement in the field of stiffened plates is mainly based on these numerical methods.

ORTHOTROPIC PLATE APPROXIMATION

The equation of motion of an orthotropic plate is

$$D_x \frac{\partial^4 w}{\partial x^4} + 2H \frac{\partial^4 w}{\partial x^2 \partial y^2} + D_y \frac{\partial^4 w}{\partial y^4} + \frac{\partial^2}{\partial t^2} \left(\rho t - I_x \frac{\partial^2 w}{\partial x^2} - I_y \frac{\partial^2 w}{\partial y^2}\right) = F(t) \quad (1)$$

D_x, D_y, and H depend on the thickness and material properties of the plate; and ρ is its mass density. The stiffened plate is reduced to an equivalent orthotropic plate.

Natural frequencies have been calculated according to Navier's solution [7,8]; a study of nodal patterns followed [9] that was modified [10] to introduce rotary inertia effects. Rotary inertia of both the plate and the stiffeners were incorporated later [11]; a nonuniformly distributed stiffener mass was used. Gumenyuk [12] proposed an approximate formula for determining natural frequencies of structurally orthotropic plates. In-plane displacements were included and treated as the product of two circular displacement functions to obtain the frequencies of an orthotropic plate [13]. This theory was used by a number of investigators [14-22] to study various types and shapes of bridge decks -- rectangular, curved, and skew girder.

The Forbenius method has been used for free vibration of bridge decks [15]; finite difference equations have been used to determine the natural frequencies of skew girder bridges [16] and to study curved girder bridges [17]. The free vibration problem of stiffened plates has been solved by assuming that the displacement function is a double trigonometric series [18-20]. The finite strip method has been used to study free vibration and response under moving load [21]; the stiffened plate was assumed to be orthotropic.

GRILLAGE APPROXIMATION

Conversion of a stiffened plate into a series of intersecting beams is popular in static analysis; work has also been reported of free vibration studies of grillages [23-26]. The transfer matrix technique has been used to determine frequencies of a grillage [23]. Omidvaran [24] considered deflection compatibility only in the vertical direction at the intersection of plate and rib in his determination of natural frequencies. He later modified the work and incorporated a shear bond between plate and rib [25]. Research on free vibration of stiffened plates and cellular

* Department of Naval Architecture, Indian Institute of Technology, Kharagpur 721 302, West Bengal, India

structures using stiffness matrix approach has recently been reported [26].

PLATE AND BEAM IDEALIZATION

Various methods have been used to treat the stiffened plate. The plate and the stiffener are considered separate.

Finite Difference Methods. Troitsky [1] has reviewed earlier work on the finite difference method [27-30]. An investigation [27] on the free vibration of plates with equidistant stiffeners was extended [28] to include torsion and in-plane forces. A corner-supported plate with edge beams has been analyzed for free vibration using 7 x7 mesh division [29]. Finite difference calculus has been used to calculate natural frequencies of stiffened plates with equally-spaced identical stiffeners [30]. Equations formulated from the variational principle for free vibration of stiffened plates have been solved by the finite difference method [31,32]. The method has extended to include in-plane inertia and in-plane displacements [33-34].

Energy Methods. The Rayleigh-Ritz method has been extensively used to study vibration problems of stiffened plates. The effect of the connections between stiffeners and the plate on natural frequency has been studied [35-37]. The characteristic beam function has been used in the Rayleigh-Ritz formulation to study free vibration [38-39]. The Lagrange equation for free vibration of rectangular and skew stiffened plates has been solved by choosing a displacement function that satisfies boundary conditions [40]. The analysis has extended to take into account torsional effects and eccentricity of the stiffeners [41]; results were also given on transient response.

Bhat [42] studied the effect on free vibration of stiffener spacing; he used the Rayleigh-Ritz method. B Spline function were chosen to satisfy boundary conditions for a free vibration analysis of stiffened skew plates [43]; various stiffening schemes and stiffening ratios were studied. Various elastic restraints along the edges have been used in a free vibration analysis [44]. Trapezoidal cantilever plates have been analyzed [45] as have shaft-supported control surfaces [46]. Madsen [47] analyzed orthogonally-stiffened panels for free vibration; he incorporated bending and warping torsion and axial deformation of the stiffener to obtain dynamic equations and applied the Rayleigh-Ritz method.

Matrix Methods. Lin and Donaldson [48] have reviewed use of the transfer matrix method to study aircraft structures [49, 50]. A transfer matrix method has been developed to predict natural frequencies and normal nodes for a finite number of panels that differ in width, thickness, and material properties [51]. Shimizu [52] generated a stiffness matrix by combining plane stress and plate bending theories. Long [53,54], in his formulation for free vibration, neglected in-plane displacements across the direction of stiffener in the dynamic stiffness matrix. Orthogonally stiffened plate structures have been analyzed using a combined finite element transfer matrix method as an automatic substructuring technique [55]. Another report has been published [56].

Finite Element Method. Considerable attention has been paid to application of the finite element method for studying vibration characteristics of stiffened plates [57-79]. Reports of early workers are available [57,58]. An assumption in one study of free vibration and random response of stiffened plates was that the stiffener is infinitely rigid [59]; warping effects of the stiffener were introduced in the form of effective torsional rigidity. Torsional effects of the stiffener were neglected in one free vibration study [60]. A non-compatible displacement function has been used for both beams and plates [62].

A nine-degree-of-freedom triangular bending element and a two-noded stiffener element were combined in one study [63]; warping of the stiffener was considered in a study of free and forced vibration. In-plane displacements and in-plane inertia were neglected.

A high-precision triangular plate bending element has been developed [64]. A refined beam bending and torsional element was incorporated in the element to analyze free and random vibration analysis [65-68]; experiments were conducted. Olson and Hazell [69-70] studied the effect of stiffness on various modes; they performed experiments using real time holography; experimental results were compared with those analytically obtained using the element. Experimental results have been compared with a finite element model consisting of a three-noded plate element with three-degree-of-freedom per node and associated with a compatible beam element [71]. Ramesh and Bekune [72] used a quadrilateral stiffened plate element with compatible and displacement functions to determine natural frequencies. Both symmetric and unsymmetric stiffeners were dealt with. Shastry and

Venkateswara Rao [73] studied arbitrarily oriented stiffeners for free vibration using a previously mentioned element [62].

The finite element method has been used in random response analysis of skin rib structures [74,75]. Central point random response and span-averaged response have been studied [77]. Available computer packages were used to solve free vibration of stiffened plates in which the length of the stiffeners varied [78].

Mukherjee and Mukhopadhyay [79] studied the free vibration of plates having symmetrically-oriented stiffeners; they used an isoparametric quadratic bending element that took into account the arbitrary orientation of stiffeners anywhere within the plate element.

Other Methods. Various analytical approaches have been used to study the dynamic characteristics of the plate stiffener system. Governing differential equations based on conditions of continuity and equilibrium at the ribs have been developed [80,81]; a Levy-type solution was sought.

A modified Bolotin method has been used for free vibration analysis of a finite row of skin stringer panels [82]. Free and forced vibrations of a curved bridge deck have been studied [83-85]. Closed form solutions for both plate and ring segments were obtained separately; frequency equations were based on continuity conditions at the junction of the plate and the ring.

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LITERATURE REVIEW: survey and analysis of the Shock and Vibration literature

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THEORETICAL STUDIES ON FLEXURAL WAVE PROPAGATION IN BEAMS: A COMPREHENSIVE REVIEW PART III: WAVE PROPAGATION IN BEAMS WITH DISCONTINUITIES OF CROSS SECTION

M.M. Al-Mousawi*

Abstract. A comprehensive review related to the problems of flexural wave propagation in beams is presented in three parts. Part I is a historical background. Part II describes the use of Timoshenko beam theory, including the effect of shear distortion and rotatory inertia, for vibrational and transient analysis of beams. Part III covers elastic stress wave propagation in beams with discontinuities of cross section.

Structural units are often of nonuniform cross-sectional area. The nonuniformity can be either a continuous variation of cross section -- e.g., tapered bars and truncated cones -- or a discontinuous abrupt change in cross section; e.g. stepped bars. In addition, nonhomogeneities in the modulus of elasticity and material density exist. Although the problem of elastic wave propagation in a rod of nonuniform cross section has been a subject of interest and investigation for decades, the problem has received relatively little attention in the literature.

Most dynamic investigations of nonuniform rods have been related to the analysis of longitudinal and flexural vibration and have been based on the one-dimensional elementary theory of longitudinal motion and the Euler-Bernoulli theory of lateral motion. However, many structures used in land, sea, air, and space vehicles are subjected to impact and transient loading. Many structural units are beams with constant cross section over a certain length; the cross section changes abruptly in another section. Such units are called stepped beams or beams with discontinuities of cross section. They are the main topic of this third part of the review.

WAVE PROPAGATION IN BEAMS WITH DISCONTINUITIES OF CROSS SECTION

Investigations of transient loads in stepped beams are limited to longitudinal wave propagation and torsional waves because they are simpler forms for theoretical treatment. Some studies related to flexural waves in tapered structures are based mostly on the Euler-Bernoulli theory, and some solutions related to flexural vibration in tapered beams are based on the Timoshenko theory.

Donnell [108] investigated the effect on a propagated longitudinal wave of a sudden change in either cross section or material of a bar. When the wave arrives at the junction, it initiates two new waves, a transmitted wave and a reflected wave. When the sudden change involved a decrease in area, the reflected wave was opposite in sign to the original incident wave. The reflected wave of a wave striking an enlarged area had the same sign as the incident wave. The transmitted wave was always of the same sign as the incident wave. Donnell also studied the problem of a gradual change in cross section and formulated a differential equation of motion for longitudinal waves that accounts for this effect. Compression forces and longitudinal velocities of particles for the bar were presented graphically, and diagrams based on energy considerations were constructed for waves produced by variable forces.

Angus [109] derived force-velocity relationships for the elastic impact of a bar composed of segments having different cross sections; he used the analogy of hydraulic equations for water hammer. His example was a bar composed of two cylinders of different diameters moving horizontally at a constant velocity. The cylinders stopped when they struck a rigid body. He showed that the stresses could be calculated by the known relation $\sigma = \rho c v$

The general equation of motion for longitudinal vibration has been used to obtain the frequency equation for an oil well pump rod consisting of a string of rods with abrupt changes in cross section [110]. The resulting natural frequencies were compared with records obtained from magnetic strain gauges located in the string of rods.

Le Van Griffis [111] discussed conditions of equilibrium of forces and particle velocities responsible for the propagation of longitudinal waves in a bar with decreased or increased area. He explained reflections at free and fixed ends as equivalent to a decrease in section to zero and an infinite increase in section respectively.

* University of Aberdeen, Department of Engineering, Kings College, Aberdeen, Scotland

Van Griffis used a characteristic propagation velocity $c=\sqrt{E/\rho}$ to construct x-t diagrams that determined a complete time-space stress function for any case of longitudinal impact. He compared the results with measurements using wire resistance strain gauges.

Robinson [112] discussed dynamic effects in an aircraft under landing conditions and traced the propagation of various kinds of stress in the structure. He used the method of characteristics to solve the equation of motion as a hyperbolic system of partial differential equations. Robinson gave a general solution for shock reflection at discontinuities in connection with abrupt changes at the junction of airplane wings. Such changes occurred in the wing root and in the vicinity of the power plant installation, where there was an abrupt change of characteristics relevant to wave propagation; i.e., stiffness and density.

Fischer [113] investigated the transmission and reflection of an elastic longitudinal rectangular pulse in a bar with a cylindrical neck or swell of varying length. The transmission and reflection of the pulse in a bar with a discontinuity of cross section was followed by a modified form of a graphodynamics method that had been applied before [114,115]. Force-velocity and space-time diagrams were used in this method to obtain stress-time and displacement-time diagrams. Fischer presented more extensive study and compared his results with experiments in a second paper [116].

Mugiono [117] used the Euler-Bernoulli equation to investigate flexural waves in beams with one and two discontinuities of cross section. He used a traveling wave solution to obtain a so-called reduction factor as a function of slenderness ratio for the propagation of bending waves relative to sound transmission through walls in buildings. Calculations and experiments were in reasonably good agreement for harmonically sinusoidal excitations.

Cranch and Adler [118] used simple beam theory to solve the problem of bending vibration of beams of rectangular cross section with any power-width variation; the depth variation was linear, quadratic, or cubic. Bessel function solutions were obtained for a truncated pyramid cantilever, a cantilever with parabolic width variation, and compound beams of similar halves joined together.

Ripperger and Abramson [119] repeated the theoretical solution of the bending wave problem in a bar with discontinuities of cross section [117]. They added a comparison with the reflection and transmission of longitudinal wave pulses and attempted to determine reflection and transmission coefficients of a stress pulse based on steady-state wave propagation. This analysis was successful for longitudinal propagation in which dispersion did not seriously alter pulse shape, but was not successful for bending wave pulses that are distorted by dispersion regardless of pulse length. It was concluded that any comparison of amplitude in bending waves is not a precise method. Reflection and transmission coefficients derived for velocity were related to corresponding quantities of moments for comparison with experimental results. Because the discrepancy between analytic and experimental results was large, it was concluded that a more accurate theoretical analysis was needed, especially for pulses of short duration.

A better agreement between theory and experiment was obtained by Habberstad and Hoge [120]. The problem of reflection and transmission of a longitudinal wave across a sudden change in cross-sectional area has been discussed [121]; equilibrium conditions for particle velocities and forces were formulated.

The concept of reflection and transmission coefficients is similar to that of the stress concentration factor used to describe the static loading of shafts subjected to torsion and bending. Allison [122] obtained elastic stress concentration factors vs diameter ratios in shouldered shafts subjected to pure bending as the quotient of peak stress in the shouldered shaft to maximum axial stress in a uniform shaft of small diameter subjected to the same moment.

Taleb and Suppiger [122] applied the Cauchy function method from the theory of integral equations. They obtained the approximate fundamental frequency and modal configuration of a stepped simply-supported beam. The solution was based on the elementary Euler-Bernoulli theory of lateral vibrations. The fundamental frequency computed after two iterations for a beam with a jump discontinuity was compared with the exact solution; it was about three percent above the exact value.

Reed [124] reported a method for computing amplitudes of a succession of pulses produced from the incidence of a single longitudinal stress pulse on a zone of many abrupt discontinuities. An identifier assigned to each pulse to describe its propagational history was used together with a pulse designator to calculate amplitude and arrival times of reflected and transmitted pulses. A numerical method was used to calculate relative

amplitudes of the members of resultant pulse trains for rods with three- and six-step transitions, for rods with stepped-cone terminations of two to ten discontinuities, and for a continuous linearly tapered cone.

Cone [125] obtained a theoretical solution for longitudinal wave propagation across an abrupt change in the cross section of a bar. He predicted a ratio for incident, reflected, and transmitted waves. The investigation was based on elementary theory; results were compared with experimental data obtained with strain gauge measurements.

Conway and Dubil [126] investigated transverse vibrational resonance frequencies of truncated cone and wedge beams for nine possible combinations of simply supported, clamped, and free end conditions. The Euler-Bernoulli equations were used to obtain solutions in the form of Bessel functions of second order. The solutions were approximated by their polynomials; numerical results were tabulated for five modes and four length ratios.

Davids and Kesti [127] compared determinations of maximum loads under impact in the design of long bars and stepped shafts; they used vibration analysis, a stress-wave propagation method, and a ramp-type pulse with a rise time of t_o. Whenever the rise time of the impact pulse exceeded the time required for the pulse to propagate the length of the bar and back about three times, an almost exact sinusoidal oscillation occurred. For a step pulse, however, the peak stress obtained by the stress wave method was almost 50 percent higher than that from the vibration method. The longitudinal waves in an actuator and pilot shaft combination designed for impact were investigated. An abrupt change of section was more successful in reducing the level of stress than a gradually changing cross section.

Beddoe [128] used Laplace transforms to obtain a transient solution to the problem of longitudinal stress waves in a cylindrical rod with several step changes in cross-sectional area. The theory was applied to a rod with a simple neck formed by two inverse changes in cross section; damping and wave dispersion effects were not considered. Results obtained by strain gauge measurement were in good agreement with the theory.

Kawata and Hashimoto [129] derived an approximate theory of dynamic-stress concentration factors. They considered notches and shoulders as discontinuities of cross-sectional area in struts. Results using high-speed photoelasticity for notched specimens of polyurethane rubber coincided with theoretical results using one-dimensional theory of longitudinal wave propagation in an elastic bar.

Lindholm and Doshi [130] were concerned with the propagation of a stress pulse in a continuously nonhomogeneous elastic bar of finite length; the elastic modulus was a function of the position in the bar. The principle of virtual work was used to synthesize a one-dimensional analysis for the propagation of longitudinal waves from eigenfunctions for the nonhomogeneous bar. Numerical results were presented for a finite free-free bar subjected to a pressure pulse and for one complete reflection in the bar. The eigenfunctions satisfied the orthogonality conditions; series expansions were evaluated for the first 30 terms. An approximate solution of the same problem was based on Laplace transforms [131].

Rosefeld and Miklowitz [132] formulated a general solution for the response of an elastic rod of arbitrary cross section to mixed end condition loading; orthogonality conditions of the eigenfunctions for displacements with different eigenvalues for frequency were employed. Laplace and Fourier transforms were introduced in order to obtain solutions in terms of harmonic waves for long-wave effects which governed long-time, large distance behavior. It was pointed out that the nature of the results for low frequencies did not depend directly on boundary shape and that the higher modes had a more complicated structure.

Yang [133] derived a general differential equation governing discontinuous wave propagation in nonuniform Timoshenko beams. A closed form solution was obtained for a nonuniform beam with a linear variation in cross section. The method of characteristics was used to formulate expressions for jumps in moment, shear, angular velocity, and transverse velocity.

Bruner and Muster [134] reported the attenuation characteristics of a typical drill-string model as a long bar with spaced discontinuities in cross-sectional area subjected to plane longitudinal acoustic waves. The analysis was based on a mechanical-electrical analogy previously used for single area discontinuities in infinitely long bars [135]; in that case the discontinuity could be represented by a shunt capacitance. Karal [136] represented the discontinuity by a series inductance. Shunt capcitance and series inductance were functions of area ratio. Bruner and Muster [134] found that attenuation peaks decreased with increasing area ratio and that attenuation

occurred at frequencies governed by the bar length at the last segment of the system.

Tsui [137] solved a projectile impinging on a target as a problem of longitudinal wave propagation in a finite length bar with power variation in the cross section. A solution was obtained for a free-free bar subjected to an arbitrary pulse; the method of separation of variables and the principle of virtual work were again used [130] for the nonhomogeneous bar. The same problem was solved by Handelman and Rubenfeld [138] using the Laplace transform method. The calculations were standard but somewhat tedious.

Kenner and Goldsmith [139] investigated the effect on longitudinal wave propagation of a thin glue section joining two adjacent cylindrical bars. The joint was treated as a short discontinuity by the one-dimensional theory; the effect of eccentric alignments on the wave transmission was also investigated. It was found that a thin insert placed between cylindrical sections disturbed wave transmission in amounts dependent on both the disparity in mechanical impedance ρc_0 with the exterior bars and the thickness of the section. The eccentricity distorted the transmitted longitudinal wave very little but decreased the peak strain up to 10 percent. The theoretical predictions were tested in experiments performed on aluminum bars glued together with two different adhesives.

Habberstad [140] formulated a two-dimensional theory for axisymmetric elastic wave propagation. He used approximations of the Pochammer-Chree equations governing axisymmetric wave propagation in cylindrical bars and a first order finite difference scheme. The numerical analysis was based on a displacement formulation used by Bertholf [141] to study the same type of wave in a uniform cylindrical rod. However, Habberstad used this numerical technique for a bar containing a discontinuity in cross section and for a bar composed of two fused materials. The same problem has been solved by the finite element method [142].

Mabie and Rogers [143] obtained the differential equation of motion for a vibrating double-tapered cantilever beam from the Euler-Bernoulli theory of transverse vibration. The frequencies of five modes were tabulated for various taper ratios. The results were obtained by numerical integration.

Three theories have been used to analyze reflection and transmission of transient longitudinal pulses in shells with discontinuous cross-sectional areas [144]. The three theories were the bending theory including transverse shear, radial inertia, and rotary inertia effect; a modified membrane theory including bending and rotary inertia; and a uniaxial theory including only axial motions. Each of the three systems of governing equations was solved by the method of characteristics. The longitudinal and circumferential incident, transmitted, and reflected strain pulses predicted by the bending and membrane theories were in good agreement with experimental results; the uniaxial theory strain predictions did not agree well with experimental results.

The method of characteristics has also been used to obtain a numerical solution according to the bending theory for the longitudinal impact of a joint cylinder-truncated cone-cylinder [145]. Good agreement was obtained in experiments carried out on a model consisting of a 1/100-scale replica of a portion of the Apollo/Saturn V vehicle.

Yang and Hassett [146] utilized the method of characteristics in the theoretical analysis of a problem of transient stress in axisymmetric bodies of varying areas. Such bodies include cones and structures with large step changes in cross-sectional area. The impedances of the bodies also varied.

Rader and Mao [147] were concerned with amplification of longitudinal pulses that propagated along tapered elastic bars. The bars were regarded as a waveguide with continuously varying impedance. A general traveling wave solution representing waveforms propagating in both directions was used. The incident wave generated an infinite sequence of reflected and refracted waves. Experimental results showed that, only for the very short and very long pulses, did the amplification approach the limiting values given by the theoretical prediction.

Reismann and Tsai [148] developed an improved theory to account for both longitudinal and radial motions. The theory was applied to two bonded, semi-infinite rods composed of different materials and to a rod of finite length bounded at each end to two semi-infinite rods composed of different materials. The results were compared with predictions of elementary rod theory as characterized by the wave equation. Plots of phase velocity vs frequency for a harmonic excitation showed that the improved theory indicated the existence of two modes.

Koenig and Berry [149] applied a direct finite analysis originally developed by Davids and Koenig [80]. Koenig and Berry obtained the transient flexural response of a cantilever ta-

pered beam and a composite beam of two different materials. The beams were subjected to a step moment input and a step velocity input. The time-histories of bending moment and shear forces were presented graphically.

Lee and Wang [150] presented a one-dimensional theory to account for longitudinal, radial, and axial shear deformation and their inertias for an elastic circular rod of nonuniform cross section. The theory was an extension of the Mindlin-McNiven theory [151]. Numerical results were obtained by the method of characteristics for several nonuniform semi-infinite and finite rods subjected to either a step or a pulse loading. The geometric effect on stresses of cross sectional variation and the effect of the elastic support on reflection and propagation of the stress were deduced. Predicted and measured results were compared.

Klein [152] investigated the transverse free vibration of elastic beams with nonuniform characteristics. He used variational analysis, either a Rayleigh-Ritz method or a finite element method. The basic assumptions of the analysis were based on the Euler-Bernoulli theory. The case of a stepped simply-supported beam was studied as a model for a nonuniform rotor blade. Comparison with experiments indicated that the theory adequately predicted natural frequencies for the first three modes and the mode shapes.

Lee and Sechler [153] used the one-dimensional theory to examine longitudinal wave propagation in wedges due to impact at their large end. Closed form solutions were obtained in terms of Laplace transforms and Bessel functions.

Gorman [154] investigated the lateral free vibration of beams with step changes in the properties of their cross section. He developed extensive tables to obtain frequencies for four modes and various end conditions. The solutions were based on the Euler-Bernoulli theory.

Ramamurti and Ramanamurti [155] used a finite difference formulation to solve the problem of longitudinal wave propagation in a very short bar with a discontinuity of cross section. Due to the symmetry in loading the problem was treated as a two-dimensional one.

Levinson [156] studied the natural frequencies of a stepped simply-supported beam using the Euler-Bernoulli theory. The frequency equation was complicated for an exact solution, even for a stepped beam consisting of only two distinct parts. It was concluded that an approximate numerical solution method should be used.

Goel [159] investigated the transverse vibration of linearly tapered beams. He tabulated results for the first three eigenfrequencies for different values of stiffness ratio and taper ratio. The analysis was based on the Euler-Bernoulli equation of motion.

Johnson [158] studied the problem of longitudinal waves in a bar with step change in cross-sectional area and material. Expressions relating the transmitted and reflected waves to the incident wave were presented. The one-dimensional theory was used.

Filippov [159] formulated general solutions for composite rod. The thickness of each finite rods was constant but differed from the other rods; composite rods had continuously varying thickness. The solutions were based on the one-dimensional theory of longitudinal wave propagation; the Heaviside function and Dirac delta function were used in the Laplace transformation.

Vasudeva an Bhaskara [160] discussed the problem of a pressure pulse in an elastic bar of finite length. The Young's modulus, material density, and cross-sectional area varied along the length in a general power form. Elementary theory was used; Laplace transformations provided general expressions for stress. The numerical values were computed by iteration for a half-sine wave pulse. Results agreed fairly well with those of Lee [161].

Gupta and Nilsson [162] studied the problem of longitudinal impact between a truncated finite conical rod and a long cylindrical rod. Contact was maintained from time of impact; the piston-rod system was considered as one structural unit. Two theoretical solutions were obtained: a closed form solution based on one-dimensional wave theory and a numerical finite element solution based on a three-dimensional axisymmetric model. Finite element results were in good agreement with experimental results; spurious oscillations were shown in the finite element solution of impact for pistons with various apex angles.

Nagaya [168] formulated an approximate numerical method for the dynamic analysis of a tapered Timoshenko beam with moving loads. Hamilton's principle was applied to obtain the equation of motion from the Lagrangian of the Timoshenko beam. Orthogonality of eigenfunctions of first and second kind was used. In the

numerical computation the effect of the inertia force on shear motion was neglected. The approximate solution was larger than that calculated from the exact Timoshenko beam with increased velocity of the load.

Hashemi [164] obtained the frequency equation and point impedance of a stepped beam using the elementary Euler-Bernoulli theory of transverse vibration. The roots of the frequency equations were obtained for the first five modes and various length-to-width ratios. Numerical results were compared with experimental results.

Al-Mousawi [165] used the Timoshenko beam theory to determine the transient response of finite beams with discontinuities of cross section subjected to eccentric longitudinal impact. A numerical solution was obtained by the method of characteristics. Theoretical predictions were in excellent agreement with experimental observations.

CONCLUSIONS

The Pochhammer-Chree theory cannot be used to obtain solutions for flexural wave propagation in finite or even semi-infinite beams with arbitrary prescribed displacement or stress distribution on the end cross section. The Euler-Bernoulli theory is inadequate because it neglects the effects of rotatory inertia and shear deformation. The Timoshenko theory takes these effects into account and gives a high degree of accuracy over a wide range of wavelengths for flexural waves in bars. This theory is applicable to flexural waves due to transverse impact as well as flexural waves due to eccentric longitudinal impact of semi-infinite and finite beams.

Continuing interest in Timoshenko beam theory during the last three decades is due to the rapid development of computing facilities, advances in experimental equipment available for producing and detecting stress waves, and the need for information on the behavior of structures subjected to impulsive loading.

Because of the difficulties involved in exact equations of elasticity, an approximate governing equation is necessary. However, for the study of transient response the derived equations must be totally hyperbolic; otherwise, their transient response is either meaningless or not obtainable.

The Timoshenko equations are the most suitable approximate equations governing flexural transient response in beams. They are approximate but do not alter the hyperbolic nature of the exact elasticity equations.

The problems of flexural wave propagation in finite beams with discontinuities of cross section has received little attention to date. Most investigations of transient waves in stepped beams are related to longitudinal and torsional wave propagation because they are governed by easier theoretical formulations.

Most published studies of flexural waves in tapered beams are based on the Euler-Bernoulli theory. The author has recently published a paper [166] that provides a theoretical solution for flexural wave propagations in beams with discontinuities of cross section according to the Timoshenko beam theory.

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BOOK REVIEWS

NOISE AND VIBRATION

Ed. R.G. White and J.G. Walker
Ellis Horwood (John Wiley) Chichester
1982, 866 pages, $122.95

This long book contains subjects taught in a short course at the Institute of Sound and Vibration Research in Great Britain. The 31 chapters were written by highly regarded authors; the book is a self-contained reference that emphasizes the analytical aspects of noise and vibration, but its broad scope and limited length make it unsuitable for use as a stand-alone text. Fortunately, the many excellent references found at the end of each chapter provide the reader with primary and secondary sources for further information.

Titles of the chapters reflect the scope of the book: Theory of acoustics, Fundamentals of vibration, Random processes, Random vibration, Data analysis, Statistical energy analysis, Nonlinear acoustics, Structural wave motion, Structure of turbulence, Structure-fluid interaction, Duct acoustics, Response of structures to noise, Jet noise, Finite elements for structures and acoustics, Noise from industrial plants, Road vehicle noise, Fan noise, Fracture mechanics, Duct design, Noise from machines, Signal processing and machine health monitoring, Measurement and diagnosis of machinery noise, Vibration control and testing, Subjective acoustics, Hearing loss and conservation, Effects of noise on people, and Human response to vibration.

A good section on nomenclature provides consistency. The subject of signal processing is treated briefly but, because so few books treat it well, is one of the highlights of Noise and Vibration.

Unfortunately, the currently popular topic acoustic intensity measurement is only mentioned; discussion of active noise control is missing. The three-year-old book is now out-of-date.

Because the authors write for a British/European readership, the test standards cited are not common in the United States except those involved in international trade. Nomenclature too may be different; for example, Q represents a magnification factor in vibration response rather than a bandwith descriptor.

On the negative side, it is difficult to understand how an author can insert a Bessel function into an introductory section of a chapter. It happens frequently, however, and is perhaps meant to impress rather than teach. Not many examples are found in this text.

The book is useful not only as a companion to several good handbooks on noise control but also by itself.

United States readers are often not exposed to books published overseas, unfortunately in this case. For if this book had been advertised in 1982 and reviewed then, its readership would probably have been significantly greater. Thus, although slighdy dated, I consider the book one of the most valuable in my collection and congratulate the editors and authors for their efforts.

R.J. Peppin
Scantek, Inc./Norwegian Electronics
12140 Parklawn Drive, Suite 465
Rockville, MD 20852

SIGNALS AND SYSTEMS

A.V. Oppenheim, A.S. Willsky and I.F. Young
Prentice-Hall, Inc., Englewood Cliffs, NJ
1983, 796 pages, $32.95

This easy-to-understand book, although designed as an undergraduate text, contains a great deal of material. As stated by the authors, "A course in signals and systems not only is an essential element in an engineering program, but also can be one of the most rewarding, exciting, and useful courses that engineering students take . . . to maximize the usefulness of this book . . ., we have chosen to present thorough, in-depth treatments of a cohesive set of topics that form the core of most introductory courses in signals and systems."

This book consists of 11 chapters and an extensive appendix. Chapter 1 introduces the concept of signals and systems. Chapter 2 presents

elementary aspects of mathematical representation of signals and systems, including transformations (time shift and scaling) of independent variables as well as basic continuous-time and discrete-time unit steps and impulses, and block diagrams. Chapter 3 describes linear time-invariant (LTI) systems. The sig als are represented in terms of impulses, the sifting property of unit impulse is expanded and used to develop convolution sums and represent discrete LTI systems. Properties of LTI are described in terms of difference and differential equations. Chapter 3 concludes with a brief discussion of singularity functions; i.e., steps, impulses, and doublets.

Chapter 4 is concerned with Fourier analysis for continuous time. Fourier analysis plays an important role in the wide range of signals that can be exhibited as a weighted sum of integrals of complex exponentials, and the reaction of an LTI system to a complex exponential multiplied by a complex number characteristic of the system. The Fourier transform is derived as a limit of the Fourier series whose period becomes large. Convolution and modulation properties provide a foundation for filtering, modulation, and sampling. The application of transform methods in analyzing LTI systems is considered.

Chapter 5 deals with Fourier analysis of discrete-time signals and systems. It follows the pattern presented in Chapter 4. The duality in continuous and discrete time Fourier representation is stressed. The specific character of each state is brought into perspective by illustrating the differences between the continuous and discrete-time Fourier analysis.

Chapter 6 introduces filters. They are described by both difference and differential equations. Butterworth filters are considered. Chapter 7 reports on modulation and describes continuous-time sinusoidal amplitude modulation (AM). Other topics include pulse-amplitude modulation and time-division multiplexing, discrete time amplitude modulation, and frequency modulation (FM).

The next chapter focuses on the sampling theorem; it is the basis of digital data processing applied to vibration and acoustics. Restoring continuous time signals via interpolation is a prime objective. Aliasing and undersampling are considered, including their ramifications to discrete time processing of continuous time signals. Chapter 9 is a good introduction to Laplace transforms, including the relations between Fourier transforms and Laplace transforms. The next chapter covers Z-transforms. The techniques of Z-transforms and Laplace transforms are used to map continuous systems with rational system functions as discrete time series with rational system functions.

The concluding chapter describes the role of Laplace and Z-transforms for investigating linear feedback systems. Root locus, Nyquist plots, and Nyquist criterion are applied to continuous and discrete time feedback systems.

Although considered elementary by the authors, this interesting volume contains a number of advanced topics. The authors have purposely omitted random signal theory and analysis. The reviewer feels that they should have been included. The reviewed believes that a table of nomenclature would be of help to the reader. Additional topics that should be covered in greater detail are fast Fourier transforms (FFT) and time series analysis. The reviewer recommends the book to those interested in processing vibration and acoustic data. Much of the information is usually not found in digital data processing books.

H. Saunders
1 Arcadian Drive
Scotia, NY 12302

SHORT COURSES

JULY

FLOW-INDUCED OSCILLATIONS IN ENGINEERING SYSTEMS
Dates: July 1-2, 1986
Place: Bethlehem, Pennsylvania
Objective: The aim of this course is to provide the practicing engineer with a means of identification and assessment of the crucial flow mechanisms and flow-structure interactions leading to vibration and noise. Throughout the course, emphasis will be given to physical and practical interpretation of the common features of problems occurring in mechanical-, aerospace-, hydraulic-, and wind-engineering areas. The course will concentrate on the physical principles of identification, analysis, and attenuation (or cure) of oscillations, followed by practical case studies, during which the instructor will cover examples from a variety of applications.

Contact: Dr. James Brown, Lehigh Director of Continuing Education, Office of Continuing Education, 219 Warren Square, Lehigh University, Bethlehem, PA 18015 - (215) 861-3934.

VIBRATION DAMPING TECHNOLOGY
Dates: July 14-17, 1986
Place: Montreal, Canada
Dates: September 15-19, 1986
Place: Dayton, Ohio
Dates: January, 1987
Place: Clearwater, Florida
Objective: Basics of theory and application of viscoelastic and other damping techniques for vibration control. The courses will concentrate on behavior of damping materials and their effect on response of damped systems, linear and nonlinear, and emphasize learning through small group exercises. Attendance will be strictly limited to ensure individual attention.

Contact: David I. Jones, Damping Technology Information Services, Box 565, Centerville Branch USPO, Dayton, OH 45459-9998 - (513) 434-6893.

FINITE ELEMENTS IN MECHANICAL AND STRUCTURAL DESIGN A: LINEAR STATIC ANALYSIS
Dates: July 14-18, 1986
Place: Ann Arbor, Michigan
Objective: Presents energy formulation and modeling concepts. For engineers requiring stress, strain and displacement information. Attendees use personal computers to develop models of several problems and use MSC/-NASTRAN in laboratory sessions. No previous finite element experience is required.

Contact: William J. Anderson, Engineering Summer Conferences, 200 Chrysler Center, North Campus, The University of Michigan, Ann Arbor, MI 48109 - (313) 764-8490

MODAL TESTING OF MACHINES AND STRUCTURES
Dates: July 14-18, 1986
Place: Rindge, New Hampshire
Objective: Vibration testing and analysis associated with machines and structures will be discussed in detail. Practical examples will be given to illustrate important concepts. Theory and test philosophy of modal techniques, methods for mobility measurements, methods for analyzing mobility data, mathematical modeling from mobility data, and applications of modal test results will be presented.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

ROTOR DYNAMICS
Dates: July 14-18, 1986
Place: Rindge, New Hampshire
Objective: The role of rotor/bearing technology in the design, development and diagnostics of industrial machinery will be elaborated. The fundamentals of rotor dynamics; fluid-film bearings; and measurement, analytical, and computational techniques will be presented. The computation and measurement of critical speeds vibration response, and stability of rotor/bearing systems will be discussed in detail. Finite elements and transfer matrix modeling will be related to computation on mainframe comput-

ers, minicomputers, and microprocessors. Modeling and computation of transient rotor behavior and nonlinear fluid-film bearing behavior will be described. Sessions will be devoted to flexible rotor balancing including turbogenerator rotors, bow behavior, squeeze-film dampers for turbomachinery, advanced concepts in troubleshooting and instrumentation, and case histories involving the power and petrochemical industries.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

ADVANCED TECHNIQUES FOR NOISE CONTROL
Dates: July 17-19, 1986
Place: Cambridge, Massachusetts
Objective: Among the topics to be covered are modern instrumentation for noise control, modal analysis, sound intensity applications, active techniques for noise control, structural and vibration transmission, and airport noise and monitoring systems.

Contact: Institute of Noise Control Engineering, P.O. Box 3206 Arlington Branch, Poughkeepsie, NY 12603.

FINITE ELEMENTS IN MECHANICAL AND STRUCTURAL DESIGN B: DYNAMIC AND NONLINEAR ANALYSIS
Dates: July 21-25, 1986
Place: Ann Arbor, Michigan
Objective: Covers vibration, material nonlinearities, and geometric nonlinearities. Includes normal modes, transient response, Euler buckling, and heat conduction. Attendees use personal computers to develop models of several problems and use MSC/NASTRAN in laboratory sessions.

Contact: William J. Anderson, Engineering Summer Conferences, 200 Chrysler Center, North Campus, The University of Michigan, Ann Arbor, MI 48109 - (313) 764-8490

FINITE ELEMENTS IN MECHANICAL AND STRUCTURAL DESIGN C: DESIGN SENSITIVITIES, CYCLIC SYMMETRY AND DMAP
Dates: July 28-August 1, 1986
Place: Ann Arbor, Michigan
Objective: Presents the use of design sensitivities and optimization (2 days), cyclic symmetry (1 day), DMAP programming (2 days). Attendees use MSC/NASTRAN to run sample problems in each topic. These methods greatly enhance the productivity and are now becoming widely used.

Contact: William J. Anderson, Engineering Summer Conferences, 200 Chrysler Center, North Campus, The University of Michigan, Ann Arbor, MI 48109 - (313) 764-8490.

AUGUST

DESIGN AND ANALYSIS OF ENGINEERING EXPERIMENTS
Dates: August 4-15, 1986
Place: Ann Arbor, Michigan
Objective: Recent developments in the field of testing, methods for designing experiments, interpretation of test data, and better utilization of the existing data. Design of experiments with a small number of test pieces or runs with high dispersion is emphasized. Obtaining maximum information from limited test data is stressed.

Contact: William J. Anderson, Engineering Summer Conferences, 200 Chrysler Center, North Campus, The University of Michigan, Ann Arbor, MI 48109 - (313) 764-8490.

RANDOM VIBRATION IN PERSPECTIVE — AN INTRODUCTION TO RANDOM VIBRATION AND SHOCK, TESTING, MEASUREMENT, ANALYSIS, AND CALIBRATION, WITH EMPHASIS ON STRESS SCREENING
Dates: August 18-22, 1986
Place: Santa Barbara, California
Dates: October 6-10, 1986
Place: Boston, Massachusetts
Dates: November 3-7, 1986
Place: Orlando, Florida
Dates: February 2-6, 1987
Place: Santa Barbara, CA
Objective: To show the superiority (for most applications) of random over the older sine vibration testing. Topics include resonance, accelerometer selection, fragility, shaker types, fixture design and fabrication, acceleration/power spectral density measurement, analog vs digital controls, environmental stress screening (ESS) of electronics production, acoustic (intense noise) testing, shock measurement and testing. This course will concentrate on equipment and techniques, rather than on mathematics and theory. The 1984 text, "Random Vibration in Perspective," by Tustin and Mercado, will be used.

Contact: Wayne Tustin, 22 East Los Olivos St., Santa Barbara, CA 93105 - (805) 682-7171.

MACHINERY VIBRATION ANALYSIS I
Dates: August 19-22, 1986
Place: New Orleans, Louisiana
Dates: November 11-14, 1986
Place: Chicago, Illinois
Objective: This course emphasizes the role of vibrations in mechanical equipment instrumentation for vibration measurement, techniques for vibration analysis and control, and vibration correction and criteria. Examples and case histories from actual vibration problems in the petroleum, process, chemical, power, paper, and pharmaceutical industries are used to illustrate techniques. Participants have the opportunity to become familiar with these techniques during the workshops. Lecture topics include: spectrum, time domain, modal, and orbital analysis; determination of natural frequency, resonance, and critical speed; vibration analysis of specific mechanical components, equipment, and equipment trains; identification of machine forces and frequencies; basic rotor dynamics including fluid-film bearing characteristics, instabilities, and response to mass unbalance; vibration correction including balancing; vibration control including isolation and damping of installed equipment; selection and use of instrumentation; equipment evaluation techniques; shop testing; and plant predictive and preventive maintenance. This course will be of interest to plant engineers and technicians who must identify and correct faults in machinery.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

VIBRATIONS OF RECIPROCATING MACHINERY
Dates: August 19-22, 1986
Place: New Orleans, Louisiana
Objective: This course on vibrations of reciprocating machinery includes piping and foundations. Equipment that will be addressed includes reciprocating compressors and pumps as well as engines of all types. Engineering problems will be discussed from the point of view of computation and measurement. Basic pulsation theory --including pulsations in reciprocating compressors and piping systems -- will be described. Acoustic resonance phenomena and digital acoustic simulation in piping will be reviewed. Calculations of piping vibration and stress will be illustrated with examples and case histories. Torsional vibrations of systems containing engines and pumps, compressors, and generators, including gearboxes and fluid drives, will be covered. Factors that should be considered during the design and analysis of foundations for engines and compressors will be discussed. Practical aspects of the vibrations of reciprocating machinery will be emphasized. Case histories and examples will be presented to illustrate techniques.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

SEPTEMBER

GEAR NOISE
Dates: September 17-19, 1986
Place: The Ohio State University
Objective: The course will cover general noise measurements and analysis, causes of gear noise, gear noise reduction techniques, dynamic modeling, gear noise signal analysis, and modal analysis of gear boxes. Problems of course attendees will be discussed in special workshop sessions. Laboratory demonstrations will also be given. Featured speakers will be mr. Donald Welbourn formerly of The University of Cambridge, and Professors D.R. Houser and R. Singh of The Gear Dynamics and Gear Noise Research Laboratory at The Ohio State University.

Contact: Mr. Richard D. Frasher, Director, Continuing Education, College of Engineering, 2070 Neil Avenue, Columbus, Ohio 43210, (614) 422-8143

NEWS BRIEFS: news on current and Future Shock and Vibration activities and events

32ND INTERNATIONAL GAS TURBINE CONFERENCE AND EXHIBIT ANAHEIM CONVENTION CENTER, ANAHEIM, CALIFORNIA

MAY 31 - JUNE 4, 1987

The ASME Gas Turbine Division's 32nd International Gas Turbine Conference and Exhibit will be held May 31 - June 4, 1987 in the Anaheim Convention Center, Anaheim, California.

All prospective authors are invited to begin now in their plans for participation. Papers on all aspects of gas turbine component, engine and system technology including research, design, development, measurement, education, application, fabrication, materials, manufacturing, control, and operational experience are welcome. More detailed calls for papers are being issued by technical committees of the division.

Technical paper offers may be initiated by submitting an abstract to the appropriate Gas Turbine Division technical committee chairman, or to the 1987 technical program chairman: D.M. Kercher, General Electric Co., Aircraft Engine Business Group, 1000 Western Avenue, M.S. 340-45, Lynn, Massachusetts 01910 - (617) 594-0667, by mid-June, 1986.

Completed manuscripts must be received by the session organizer or technical committee chairman no later than **mid-September, 1986.** First time authors are encouraged to study ASME Manual MS-4, "An ASME Paper", prior to preparation of their manuscript. All papers will be reviewed in accordance with established ASME and Gas Turbine Division policy and procedures and will be eligible for ASME Journal publication if warranted by reviews.

REVIEWS OF MEETINGS

ASME DESIGN ENGINEERING TECHNICAL CONFERENCES

September 11-13, 1985
Cincinnati, Ohio

The 1985 Design Engineering Technical Conferences included the following meetings: The Design Automation Conference; The Vibrations Conference; and The Failure Prevention and Reliability Conference.

While all of the above meetings contained papers of interest to the Shock and Vibration technical community, most of the papers of interest to the Shock and Vibration technical community were programmed in the Vibrations Conference with contained multiple sessions on the following subjects: Rotor Dynamics (Six Sessions); Damping (Three Sessions); Fluid-Structure Interaction (Two Sessions); Structural Dynamics (Five Sessions); Data Acquisition and Analysis (Two Sessions); Bladed Disk Assemblies (Three Sessions); and Experimental and Analytical Modal Analysis (Two Sessions). Single sessions were organized to deal with the following subjects: Mechanical Equipment Noise; Mechanical Signature Analysis; Gear Geometry; and Gear Stresses.

The combination of the number of simultaneous sessions and the number of papers that were presented in each session makes it necessary to limit this report to a sample of the many papers that were presented.

In the first part of the Experimental and Analytical Modal Analysis Session I, G. Lallement, Z. Zhang, and R. Fillod discussed the use of the "Additional Masses" technique to identify the modes of self-adjacent and non self-adjacent structures. Possible uses of this technique include the analysis of modified structures and stability and control analyses.

The second part of the Rotor Dynamics II sessions contained three papers. M. Darlow described the use of microcomputers for dynamic analysis of rotor-bearing systems. He briefly discussed the characteristics of microcomputers and methods for implementing rotor-dynamics analyses on relatively small microcomputers. K. Spanyer described the effects of systems variables on the stability of rotor systems. A. Muszynska and D. Bently described the results of their research into rotor-bearing system response in the range of perturbing frequencies in the oil whirl or oil whip regimes.

In the Mechanical Signature Analysis session, P. Cawley discussed the accuracy of frequency response function measurements made with impact excitation and FFT based analyzers. He discussed two methods for computing the frequency response functions, the effect of noise on the input and output signals for each computational method, and the effects of bias errors on the frequency response function estimates. S. Braun and J. Levran described a technique for extracting the mode shapes of operating machinery from in-place acceleration measurements. They used the measurement of the mode shapes of the structure of an operating machine tool to demonstrate their technique.

The second part of the Rotor Dynamics III session contained three papers. E.S. Zorzi and C.C. Lee described a finite element based method that can be used to rapidly and efficiently predict the damped natural frequencies and mode shapes of a large rotor system. The authors used the extraction to the damped eigenvalues and eigenvectors from a boiler feed pump turbine to demonstrate the viability of their technique. J.C. Giordano and E.S. Zorzi described a combined analytical and experimental program to evaluate the rotordynamic behavior of fibrous composite material shafts. They undertook their research to assess the ability of existing analytical methods for predicting the dynamic behavior of composite material shafts, to determine the sensitivity of composite material shafts to unbalance, and to determine the critical speed payoff. The critical speed payoff is the percentage increase in the critical speed of a composite material shaft compared to the critical speed of a metal shaft of the same geometry.

Two sessions on Failure Prevention Through Vibration Monitoring were held as a part of the conference on Failure Prevention and Reliability. In the first of these two sessions, S.M. Norris presented suggested guidelines for the levels of vibration for assessing the condition of machine tools. He discussed the considerations in arriving at the guidelines, and these included the methods of making the measurements, the measurement

units, and the closeness of the tolerances in the end product. C.B. Meher-Homji and A.B. Focke discussed the use of both vibration monitoring and performance monitoring to detect impending failures in gas turbine blading. They described some of the blade vibration problems that may be found in the compressor and the turbine sections of gas turbines, and they discussed the relation of measured vibration and performance parameters to conditions indicative of problems in turbomachinery blading. S.A. Cook, et. al., described microprocessor based remote stations for monitoring the vibrations in vertical pumps for cooling nuclear reactors.

In the second of the two sessions on Failure Prevention Through Vibration Monitoring, R.H. Kim presented a case history where vibration measurements were made on the bearings of centrifugal blowers to determine the causes of frequent failures of the bearings.

J.C.S. Yang and W.H. Tsai discussed the use of system identification techniques for detecting the location of damage in complex structures such as cantilever beams, plates, and an offshore oil drilling platform.

R.H.V.

ABSTRACTS FROM THE CURRENT LITERATURE

ABSTRACT CONTENTS

AVAILABILITY OF PUBLICATIONS ABSTRACTED

None of the publications are available at SVIC or at the Vibration Institute, except those generated by either organization.

Periodical articles, society papers, and papers presented at conferences may be obtained at the Engineering Societies Library, 345 East 47th Street, New York, NY 10017; or Library of Congress, Washington, D.C., when not available in local or company libraries.

Government reports may be purchased from National Technical Information Service, Springfield, VA 22161. They are identified at the end of bibliographic citation by an NTIS order number with prefixes such as AD, N, NTIS, PB, DE, NUREG, DOE, and ERATL.

Ph.D. dissertations are identified by a DA order number and are available from University Microfilms International, Dissertation Copies, P.O. Box 1764, Ann Arbor, MI 48108.

U.S. patents and patent applications may be ordered by patent or patent application number from Commissioner of Patents, Washington, D.C. 20231.

Chinese publications, identified by a CSTA order number, are available in Chinese or English translation from International Information Service, Ltd., P.O. Box 24683, ABD Post Office, Hong Kong.

Institution of Mechanical Engineers publications are available in U.S.: SAE Customer Service, Dept. 676, 400 Commonwealth Drive, Warrendale, PA 15096, by quoting the SAE-MEP number.

When ordering, the pertinent order number should always be included, not the **DIGEST** abstract number.

A List of Periodicals Scanned is published in issues, 1, 6, and 12.

MECHANICAL SYSTEMS

ROTATING MACHINES

86-1157
Dynamic Characteristics of Spindle-Bearing System in Machine Tools
Masaomi Tsutsumi, In Sung Chung, Yasunori Murkami, Yoshimi Ito
Tokyo Inst. of Technology, Tokyo, Japan
Bull. JSME, 28 (244) pp 2460-2466 (Oct 1985) 15 figs, 3 tables, 10 refs

KEY WORDS: Lathes, Spindles, Roller bearings, Mathematical models

In this paper, a mathematical model of a lathe spindle supported by rolling element bearings is proposed; the main spindle is expressed by the Timoshenko beam and the rolling bearings are represented by springs and dashpots in radial and angular directions. Comparing calculations with the experimental results, the mathematical model proposed here is found to be superior to the conventional model. The dynamic characteristics of the spindle-bearing system are simulated by the proposed model. From the calculated results, it is clear that the damping property of the system is dependent on only the angular damping. The natural frequency is dependent on the radial stiffness. Moreover, the damping property of the system is affected by both front and rear bearings.

86-1158
Vibration and Balance of Gyro Spin Motors
Wan De-jun, Zhou Bai-ling
Ship Engrg., (3), pp 46-54 (1985) CSTA No. 623.8-85.26

KEY WORDS: Shafts, Ball bearings, Natural frequencies, Vibration control

This paper discusses the natural frequency of the stator shafts, vibration of the ball bearings, and dynamic balance of the gyro spin motors. Some effective ways for restraining the vibration of the motors are suggested to improve their accuracy, service life, and reliability.

86-1159
Modal Test and Computer Analysis of Dynamic Parameters for a Rotor
Zhu Kunquan, Chen Shilin
J. Wuhan Inst. Bldg. Material, (1), pp 55-64 (1985) CSTA No. 691-85.05

KEY WORDS: Shafts, Experimental modal analysis, Computer programs

This paper deals with the dynamic characteristic analysis for a system with nonuniform rotating shaft by modal test and theoretical calculation. The methods of parameter identification through a graphical modal and theory of transfer matrices were used, respectively. The results are in agreement.

86-1160
Unbalance Response of Rotor Disks Supported by Fluid Film Bearings with a Negative Cross Coupled Stiffness Using Influence Coefficient Method
A.M. Sharan, J.S. Rao
Memorial Univ. of Newfoundland, St. John's, Newfoundland, Canada
Mech. Mach. Theory, 20 (5), pp 415-426 (1985) 11 figs, 1 table, 16 refs

KEY WORDS: Rotors, Disks, Fluid-film bearings, Influence coefficient method, Unbalanced mass response

The dynamic response of a multidisk rotor system supported by fluid-film bearing using the method of influence coefficients is presented. The stiffness and the damping coefficients have been considered as speed dependent. The two bearings, which support the rotor shaft, are dissimilar. The dynamic response is calculated by varying parameters such as spacing between the disks, the viscosity ratio of the oil of the bearings, the bearing clearance ratio and the relative mass of the rotor disks. The effect of damping on the rotor response and the critical speed is also presented.

86-1161
Damping Subsynchronous Frequency Oscillations in Power Systems Using a Static Phase-Shifter
M.R. Iravani
Ph.D. Thesis, The Univ. of Manitoba, Canada (1985)

KEY WORDS: Shafts, Subsynchronous vibration, Vibration damping

A new method for damping the Subsynchronous frequency Oscillations (SSO) in power systems is suggested. The supplementary damping is

achieved based on the active power modulation characteristics of the static phase-shifters, using the rotor speed deviation from the synchronous speed as the control signal. The complex torque coefficient method and an eigenvalue analysis technique are used for small signal analysis and optimization of the parameters of the control system. The analytical results are verified by a detailed digital time simulation study on the first IEEE benchmark model for SSO, using the Electro-Magnetic Transients Program (EMTP) developed by the Bonneville Power Administration (BPA). The results from the analytical and the digital computer studies reveal the technical feasibility of using a static phase-shifter for damping the shaft torsional stresses of a turbine-generator.

86-1162
Nonlinear Equations for Dynamics of Pretwisted Beams Undergoing Small Strains and Large Rotations
D.H. Hodges
NASA Ames Res. Ctr., Moffett Field, CA
Rept No. NASA-A-9833, NASA-TP-2470, AVSCOM-TR-84-A-5, 36 pp (May 1985) AD-A156 934/2/GAR

KEY WORDS: Beams, Helicopters, Rotors

Nonlinear beam kinematics are developed and applied to the dynamic analysis of a pretwisted, rotating beam element. The assumption of moderate rotations caused by structural deformation in geometric nonlinear analysis of rotating beams has been abandoned. The kinematic relations that describe the orientation of the cross section during deformation are simplified by systematically ignoring the extensional strain compared to unity in those relations. Open cross section effects such as warping rigidity and dynamics are ignored, but other influences of warp are retained. The beam cross section is not allowed to deform in its own plane. Various means of implementation are discussed, including a finite element formulation. Numerical results obtained for nonlinear static problems show

86-1163
Lateral Vibrations of a Rotating Shaft Driven by a Universal Joint
Hiroshi Ota, Masayoshi Kato, Hiroshi Sugita
Nagoya Univ., Chikusa-ku, Nagoya, Japan
Bull. JSME, 28 (242), pp 1749-1755 (Aug 1985) 8 figs, 2 tables, 6 refs

KEY WORDS: Shafts, Lateral vibrations, Whirling

This study deals with even multiple vibrations, namely, forced vibrations due to whirling with even multiple of drive shaft speed. A secondary moment is considered as the cause of the even multiple vibrations and its characteristics are investigated by analyses and experiments. The secondary moment is generated in a universal joint by loads against rotation of a driven shaft and it acts perpendicularly to the driven shaft. The loads consist of a constant resisting moment and a moment for the torsional vibration of the driven shaft based on the mechanism of a universal joint. The even multiple vibrations due to the former load differ from those due to the latter load in characteristic.

86-1164
Some Factors Affecting the Difference Between the Computation and the Measurement of the Torsional Vibration of the Engine Crankshaft
Gao Pinxian
CSICE, 3 (1), pp 31-38 (1985) CSTA No. 621.43-85.46

KEY WORDS: Crankshafts, Torsional vibrations

The torsional vibration of the engine crankshaft is an important subject in the development of engines. At present, both the theoretical computation and the practical measurement are commonly used for the research in vibration. There is quite a large gap between them. In order to find out the main factors causing the difference, avoid or reduce their effects, and increase the practical value of the theoretical computation, this paper makes a preliminary investigation into some important factors. Diesel engines are used as an example.

86-1165
Inproved Turbopump Dynamics
L. Kiefling
NASA George C. Marshall Space Flight Ctr., Huntsville, AL
Rept. No. NASA-TM-86514, 6 pp (July 1985) N85-31509/1/GAR

KEY WORDS: Pumps, Turbomachinery, Critical speeds, Design techniques, Lasers

A study was initiated to investigate the practicality of increasing rotor critical speeds by the changes in manufacturing method. The technique would be to build a pump with an all laser welded shaft and case. Such a unit would be opened by laser cutting and rebuilt by rewelding

the same surface. Use of a split casing, common in industry, would permit assembly of the rotor outside the case. Although very limited results were achieved, nothing was found to indicate that the method is not worth further investigation.

86-1166
Optimum Design of Rotating Machine with Overhung Weight
Atsuo Sueoka, Hideyuki Tamura, Yoshihiro Tsuda, Makoto Samejima
Kyushu Univ., Higashi-ku, Fukuoka-shi, Japan
Bull. JSME, 28 (243), pp 2064-2072 (Sept 1985)
13 figs, 2 tables, 4 refs

KEY WORDS: Rotating machinery, Optimum design, Critical speeds

This paper describes the numerical and the experimental results on optimum problems analytically formulated for rotating machine with an overhung weight and a shaft.

RECIPROCATING MACHINES

86-1167
Low Speed Hunting of the Pneumatically Governed Compression-Ignition Engine
Yoshihiko Kawazoe
Saitama Inst. of Technology, Saitama, Japan
Bull. JSME, 28 (243), pp 2022-2027 (Sept 1985)
13 figs, 27 refs

KEY WORDS: Diesel engines, Hunting motion

The purpose of this study is to reveal the mechanism of low speed hunting peculiar to the pneumatically governed engine. In the present report, it is shown that the conventional linear theory on the engine-governor system does not explain the actual phenomena.

The Finite Element Analysis for Vibration Character of Internal Combustion Engine
Chen Jun-Hua
Chinese Internal Combustion Engine Engrg., 6 (2), pp 46-52 (1985) CSTA No. 621.43-85.66

KEY WORDS: Internal combustion engine, Finite element technique, Vibration damping, Noise reduction

The vibration character of the spark ignition engine and its major components are calculated with the finite element analysis method. Some measures of vibration damping and noise reduction are recommended.

METAL WORKING AND FORMING

86-1169
A Modal Synthesis Method of Machine Tool Structure
Peng Ze-min, Wang Guang-fu
JTJU (2), pp 35-46 (1985) CSTA No. 621.8-85.08

KEY WORDS: Mode shapes, Machine tools

This paper presents a new method, based on static and dynamic experiments of various machine tool components, and then put through assembly step by step for modal synthesis. The static test is to obtain attachment modal matrix, while the dynamic test, to get the reserve modal information. A case study is presented in this paper.

86-1170
The Effects of Damping Capacity at the Chuck-Workpiece System on the Chatter Vibration
Masahiro Doi, Masami Masuko, Yoshimi Ito
Musashi Inst. of Technology, Tokyo, Japan
Bull. JSME, 28 (242), pp 1768-1174 (Aug 1985)
10 figs, 8 refs

KEY WORDS: Machine tools, Damping effects, Chatter

In this paper, the effects of damping capacity at the chuck-workpiece system on the surface roughness in chatter vibration were investigated, experimentally. The damping capacity of the system was varied with several chucking conditions.

86-1171
Identification of the Machine Tool Structural Parameters by Time Series and Finite Element Method Using Condensation Technique
Yuan Jingxia, Tang Xiujin
Chinese J. Mech. Engrg., 21 (2), pp 1-12 (1985)
CSTA No. 621.8-85.01

KEY WORDS: Machine tools, Parameter identification technique, Finite element technique, Time series analysis method

The identification of the joint structural parameters of a machine tool is one of important elements for improved and efficient design. In this paper, a new method for combining the time series analysis with finite element model, by using condensation technique, is presented. Joint structural parameters are identified.

86-1172
Dynamic Characteristics of Spindle-Bearing System in Machine Tools
In-Sung Chung, Masaomi Tsutsumi, Yoshimi Ito
Jeon Bug Nat. Univ., Jeonju, Korea
Bull. JSME, 28 (242), pp 1782-1788 (Aug 1985) 17 figs, 8 refs

KEY WORDS: Machine tools, Spindles, Rolling contact bearings, Damping coefficients

The influences of the bearing type and mounting method of a V pulley on the frequency response of a lathe spindle supported by rolling bearings were experimentally investigated. The bearing-preload was varied. Also, the magnitude of the maximum negative real part of the receptance was investigated. Based upon the experimental results, it was found that the damping properties of the work-spindle system are largely affected by the type of the main bearing and the mounting method of the pulley.

86-1173
Dynamics of Roller Cone Bits
D. Ma, J.J. Azar
Univ. of Tulsa, Tulsa, OK
J. Energy Resources Tech., Trans. ASME, 107 (4), pp 543-548 (Dec 1985) 9 figs, 6 refs

KEY WORDS: Drills

This paper attempts to develop an analytical tool to quantify the tooth action in roller cone bits. It is based on tests, geometry analysis and statistics.

86-1174
On the Prediction of Impact Noise, Part IX: The Noise from Punch Presses
E.J. Richards, G.J. Stimpson
Univ. of Southampton, Southampton, England
J. Sound Vib., 103 (1), pp 43-81 (Nov 8, 1985) 34 figs, 4 tables, 20 refs

KEY WORDS: Presses, Impact noise, Noise prediction

This paper describes the way the energy accountancy equation can be modified to relate the noise radiated directly to the sums of the squares of the large rates of change of force against time. It illustrates clearly the way that noise control, with use of passive or active methods in designing the punch tooling, can be related directly to the parameter. It is shown that noise levels can be reduced by up to 30 dB under ideal conditions by fracture pulse tailoring while still cutting metal. More realistically, 10 dB reductions may be obtained below those of current practice by practical tool design. An explanation is given of why large open presses are never likely to achieve the proposed factory noise levels and that the noise from double-sided presses can be controlled effectively by tooling modifications and by the addition of damping.

STRUCTURAL SYSTEMS

BRIDGES

86-1175
Finite Element Analysis of Suspension Bridges
S.G. Arzoumanidis, M.P. Bieniek
Columbia, Univ., New York, NY
Computers Struc., 21 (6), pp 1237-1253 (1985) 18 figs, 30 refs

KEY WORDS: Suspension bridges, Finite element technique, Wind-induced excitation, Moving loads

A finite element analysis of static and dynamic response of suspension bridges is presented in this paper. Several finite element models of the three-dimensional bridge structure, with varying degrees of complexity and accuracy, are discussed. Examples of application include calculations of the static and dynamic response of a bridge subjected to wind and moving loads.

86-1176
A Study of Railway Bridge/Vehicle Interaction and Evaluation of Fatigue Life
V.K. Garg, K.H. Chu, T.L. Wang
Univ. of Maine, Orono, ME
Earthquake Engrg. Struc. Dynam., 13 (6), pp 689-709 (Nov/Dec 1985) 19 figs, 4 tables, 21 refs

KEY WORDS: Railroad bridges, Bridge-vehicle interaction, Fatigue life, Moving loads

A new vehicle model and the partial bridge model were used to study the dynamic interaction between an open deck steel truss bridge and a moving freight train. The responses in terms of dynamic stresses in certain critical members in the bridge were generated to predict their fatigue lives by using a reliability-based methodology.

86-1177
Seismic Study of Curved Bridges Using the Rayleigh-Ritz Method
P.C. Chang, C.P. Heins, Li Guohao, Shi Ding
Univ. of Maryland, College Park, MD
Computers Struc., 21 (6), pp 1095-1104 (1985) 10 figs, 9 tables, 9 refs

KEY WORDS: Bridges, Seismic response, Mode shapes, Rayleigh-Ritz method

The determination of the static and seismic response of curved girder bridges is important and difficult. The purpose of this paper is to present a direct method for evaluating accurately the mode shapes and the final seismic actions of continuous curved girders supported on high piers, with minimum computation time, using the Rayleigh-Ritz method.

86-1178
Development of Two Algorithms Using a Dynamic System to Study the Interaction Between the Vehicle and the Road Profile at the Site of the Expansion Joints in Bridge Decks (Deux Methodes de Calcul en vue de la Determination des Forces Dynamiques Exercees sur un Profil Routier par un Vehicule a Essreu Simple et leur Verification Experimentale)
C. Clauwaert
Centre de Recherches Routieres, Brussels, Belgium
Rept. No. CR-24/84, 84 pp (1984) PB85-233252/GAR (in French)

KEY WORDS: Bridges, Expansion joints, Road-vehicle interaction

The study was carried out as part of an investigation of the mechanical behavior of expansion joints in bridge decks. The expansion joints have in the last years represented a major item in bridge maintenance policies. The works involved usually entail the repair of complete replacement of the joint and often of the surrounding areas as well. Although there are studies on the road profile-vehicle interaction in the literature, it was decided to develop to algorithms which dealt with the problem more directly. Both algorithms developed uses a dynamic system with two degrees of freedom so that when applied the measurements remain limited but the main variables of the problems are nevertheless identified.

BUILDINGS

86-1179
Seismic Tests on Models of Reinforced-Concrete Category I Buildings
R.C. Dove, E.G. Endebrock, W.E. Dunwoody, J.G. Bennett
Los Alamos National Lab., NM
Rept No. LA-UR-85-725, CONF-850809-17, 13 pp (1985) (International Conf. on Struc. Mech. in Reactor Tech., Brussels, Belgium, Aug 19, 1985) DE85007684/GAR

KEY WORDS: Buildings, Reinforced concrete, Nuclear power plants, Seismic tests, Experimental data

The behavior of reinforced concrete Category I noncontainment nuclear power plant structures subjected to seismic events of magnitude greater than used in their original design has been investigated. Two sizes of scale models were used. Test results were analyzed to determine maximum input for the response to remain linear/elastic; and changes in stiffness, damping, and modal frequency that are produced by seismic input greater than that causing linear elastic response. Changes in floor response spectra when the structure response is nonlinear/inelastic; and the magnitude of the seismic event necessary to fail (excessively crack) these structures were investigated. By constructing models of two sizes, it was possible to make two independent predictions of prototype behavior and to compare the results from the two models.

FOUNDATIONS

86-1180
Dynamic Characteristics of Soil-Foundation Interaction System Detected from Forced Vibration Test and Earthquake Observation
Katsuhiko Ishida
Central Research Institute of Electric Power Industry, Chiba, Japan
Earthquake Engrg. Struc. Dynam., 13 (6), pp 799-825 (Nov/Dec 1985) 22 figs, 1 table, 13 refs

KEY WORDS: Rock foundations, Soil-foundation interaction, Vibration tests, Seismic excitation

This paper presents some results on the following subjects obtained from in-situ forced vibration tests and earthquake observations. The characteristics of the radiation damping of soil-foundation interaction systems vs non-dimensional frequency were experimentally estimated by equivalent damping ratios, which were defined by complex stiffnesses of soil. The results for base rock were compared with those of soft soil. A comparative study of experimental and theoretical results was made. The theoretical results were obtained from elastic half-space theory. A semi-empirical equation to estimate the equivalent S-wave velocity for the elastic half-space model is proposed here, considering the effects of layered media. Various comparisons of the results forced vibration tests and earthquake observations were made.

86-1181

A Preliminary Study on the Effects of the Joints and Cracks to the Dynamic Properties of the Rock Mass and Its Structure

Wang Qizheng

J. Hydraulic Engrg., (2), pp 22-29 (1985) CSTA No. 627-85.11

KEY WORDS: Joints, Rocks, Cracked media, Discontinuity-containing media

The dynamic analyses of two groups of column rock structure including eight cases of joints are carried out by finite element method. The effects of joints on the dynamic elastic modulus of the material and on the natural dynamic behavior of the column structure are obtained. The results show that the dynamic response for a simple structure with joints can be estimated using a dynamic analysis of the structure without joint which has orthogonal anisotropic property. This conclusion is demonstrated by the results of the dynamic model test for a plane slice of a hill with joints.

86-1182

Non-Linear Axisymmetric Vibration of Orthotropic Thin Circular Plates on Elastic Foundations

P.C. Dumir, Ch. R. Kumar, M.L. Gandhi

Indian Institute of Technology, New Delhi, India

J. Sound Vib., 103 (2), pp 273-285 (Nov 22, 1985) 9 figs, 3 tables, 24 refs

KEY WORDS: Circular plates, Elastic foundations, Axisymmetric vibrations

This study deals with the large amplitude axisymmetric free vibrations of cylindrically orthotropic thin circular plates resting on elastic foundations. Geometric non-linearity due to moderately large deflections has been included. Movable and immovable simply supported plates and immovable clamped plates resting on Winkler, Pasternak and nonlinear Winkler foundations have been considered. The effects of foundation parameters, the orthotropic parameter and the edge conditions on the nonlinear vibration behavior have been investigated.

86-1183

A Simplified Method for Treating the Dynamic Response of Embedded Structures to SH-Waves

D.P. Thambiratnam, T. Balendra

National Univ. of Singapore

J. Sound Vib., 103 (2), pp 287-296 (Nov 22, 1985) 8 figs, 15 refs

KEY WORDS: Soil-structure interaction, Underground structures, Foundations, Strip method, Shear waves

A simplified method is proposed to treat the dynamic response of rigid embedded structures subjected to plane SH-waves. The soil-structure interface is discretized into a finite number of strips, resulting in an analysis which involved only plane surfaces and plane waves. The interaction force on any strip is determined easily and the contributions from all the strips are superposed to obtain the total force on the structure. The equation of motion then yields the steady state response of the structure. The Green function for the structure is obtained by Fourier synthesis. The transient response of the structure to any other excitation is then obtained by using the Green function and the Duhamel integral. Numerical examples are presented both to validate and illustrate the method.

86-1184

Simple Model for Transient Soil Loading in Earthquake Analysis. I. Basic Model and Its Application

O.C. Zienkiewicz, K.H. Leung, M. Pastor

Univ. of Wales, Swansea, UK

Intl. J. Numer. Anal. Methods Geomech., 9 (5), pp 453-476 (Sept/Oct 1985) 11 figs, 32 refs

KEY WORDS: Soils, Seismic analysis

Several models describing soil response under cyclic loading and the 'liquifaction' potential have

been introduced in recent years with limited success. Most of these are over-complex for realistic parameter identification and have not been widely adopted for practical use. In this paper a relatively simple modification of the well-known critical state model which accounts reasonably well for the phenomena observed under cyclic tests and improves the performance of critical state models in monotonic loading is introduced. This model is compared with experimental results and with the densification model introduced earlier by the authors and shows good predictive capacity. The model is of a generalized plasticity-bounding surface type. In its simplest form, suitable for clay-like materials, it requires the identifications of a single parameter additional to those required for a standard, critical state model.

UNDERGROUND STRUCTURES

86-1185
Aseismic Design of Underground Structures
C.M. St. John, T.F. Zahrah
Agbabian Associates, El Segundo, CA
Rept. No. AA-R-8411-5616, 138 pp (June 1985) PB85-235968/GAR

KEY WORDS: Underground structures, Seismic design

This study defines the basis for the aseismic design of subsurface excavations and underground structures. It includes a definition of the seismic environment and earthquake hazard, and a review of the analytical and empirical tools that are available to the designer concerned with the performance of underground structures subjected to seismic loads. Particular attention is devoted to development of simplified models that appear to be applicable in many practical cases.

HARBORS AND DAMS

86-1186
Response of Jointed Arches to Earthquake Excitation
J.F. Hall, M.J. Dowling
Caltech, Pasadena, CA
Earthquake Engrg. Struc. Dynam., 13 (6), pp 779-798 (Nov/Dec 1985) 20 figs, 1 table, 14 refs

KEY WORDS: Joints, Slabs, Arch dams, Concrete, Seismic excitation

An efficient method for accurately modeling the gradual opening and closing of joints in two-dimensional slabs and arches has been devised. The method is used in computing the earthquake response of an arch which is a representative horizontal cross section of a concrete arch dam. Responses of the arch with and without joints are compared to assess the effect of joint opening. An extension to three-dimensional arch dams is proposed.

86-1187
The Seismic Stress Intensity Factors of Horizontal Crack on the Face of Gravity Dams
Jing Zhou
J. Hydraulic Engrg. (4), pp 18-26 (1985) CSTA No. 627-85.38

KEY WORDS: Dams, Seismic analysis, Crack propagation

In this paper the energy method is employed to determine the modal stress intensity factors of concrete gravity dams under seismic loading. By superposition, the maximum stress intensity factor can then be obtained.

ROADS AND TRACKS

86-1188
Study on Contact Rolling Fatigue of Rails
Shin-ichi Nishida, Chikayuki Urashima, Kazuo Sugino, Hiroki Masumoto
Nippon Steel Corp., Kitakyushi, Japan
Bull. JSME, 28 (243), pp 1819-1824 (Sept 1985) 8 figs, 2 tables, 12 refs

KEY WORDS: Rails, Fatigue life, Contact vibration, experimental data, Rail-wheel interaction

This is a report on the results obtained by using a high speed rail testing machine. The contact rolling defects of the actual rail were observed in the laboratory. Especially, the running surface layer of the rail was investigated in detail and the possibility of surface crack propagation was analyzed by fracture mechanics. Defects on the running surface are shown by direction and a little in the opposite direction. Head checks at the gauge corner show many cracks occur at the gauge corner with the same pitch and with the same inclination to the wheel direction.

86-1189
Study on Contact Rolling Fatigue of Rails (1st Report, Development of High Speed Rail Testing Machine)
Shin-ichi Nishida, Chikayuki Urashima, Kazuo Sugino, Hiroki Masumoto
Nippon Steel Corp., Kitakyushi City, Japan
Bull. JSME, 28 (243), pp 1814-1818 (Sept 1985) 5 figs, 3 refs

KEY WORDS: Rails, Fatigue tests, Test equipment, Contact vibration, Rail-wheel interaction

The high speed rail testing machine was originally developed in the world to simulate the Shinkansen traffic condition in Japan, especially the contact rolling problems between rail and wheel in a laboratory. Its main features are as follows. This machine is of a unique type and principally consists of a circular rail and two wheels, which contact each other.

86-1190
Ground Vibrations in the Vicinity of Shallow Railroad Tunnels and Open Tracks (Erschütterungen in der Umgebung von flach liegenden Eisenbahntunneln im Vergleich mit freien Strecken)
Von U.J. Kurze, R. Wettschureck
Müller-BBM GmbH, Planegg bei Munchen
Acustica, 58 (3), pp 170-176 (Aug 1985) 7 figs, 10 refs (in German)

KEY WORDS: Railroads, Ground vibration

Vibrations observed on the ground surface adjacent to shallow tunnels are somewhat weaker than vibrations near open tracks in the low frequency range around 20 Hz, but are similar at higher frequencies around 50 Hz. The observations are analyzed by means of a theoretical impedance model developed for the calculation of the insertion loss provided by the tunnel base plate. The impedances of wheel sets, rails on sleepers, ballast, the prepared soil and the tunnel base plate are estimated. The calculations seem to be appropriate for the description of the observations, in spite of particular local effects that result in the shifting of resonance and quantitative differences due to neglected effects of energy flow.

CONSTRUCTION EQUIPMENT

86-1191
The Modal Synthesis for Tractor-Mounted Implement System
Du Chang-qing
Trans. of Chinese Soc. of Agri. Mach., 16 (1), PP 1-11 (1985) CSTA 631.3-85.01

KEY WORDS: Modal synthesis, Tractors, Agricultural machinery, Mode shapes, Natural frequencies

In this paper, a free-interface modal synthesis method for the dynamic analysis of tractor-mounted implement system is described. The rigid-body modes, the incomplete set of normal modes and the residual flexibility of the substructures are employed. The coupling of the substructures can be performed by using force equilibrium and displacement compatibility equations at the interface.

86-1192
Study on Dynamic Stability of a Truck Crane Carrier
Hiroshi Ito, Mitsuhiko Hasegawa, Tsukasa Irie, Yoshio Kato
Bull. JSME, 28 (244), pp 2467-2473 (Oct 1985) 9 figs, 1 table, 4 refs

KEY WORDS: Cranes (hoists), Trucks, Dynamic stability

This paper deals with the forward stability of a truck crane for lowering the loads. Using a mathematical simulation model developed from the model for the backward stability in the first report, the behavior of a truck crane overturning in the direction of the lifted load in a sudden stop operation during lowering is theoretically analyzed. Effects of crane specifications and constants on the dynamic forward stability are revealed. Thus, an accurate prediction of the stability of a truck crane can be made in the design stage.

86-1193
Study on Dynamic Stability of a Truck Crane Carrier
Hiroshi Ito, Mitsuhiko Hasegawa, Tsukasa Irie, Yoshio Kato
Technological Univ. of Nagaoka, Niigata, Japan
Bull. JSME, 28 (244), pp 2467-2473 (Oct 1985) 11 figs, 4 refs

KEY WORDS: Cranes (hoists), Trucks, Dynamic stability

This paper is a continuation to the previous report on the forward stability of a truck crane. The analysis based on a strict simulation model

gives precise results but is too complicated for practical use. Here an approximate method using a simplified simulation model is proposed to analyze the behavior of a truck crane overturning in the direction of the lifted load by sudden stop during load lowering. Thus the minimum acceptable forward stability of a truck crane can be easily determined. Effects of crane specifications and constants on the stability have also been clarified.

POWER PLANTS

86-1194
Dynamic Response of Cylindrical ACS Support Structures to Core Energy Release
J.M. Kennedy, T.B. Belytschko
Argonne National Lab., IL
Rept. No. CONF-850809-50, 13 pp (1985) (Pres. at Intl. Conf. Struc. Mech. in Reactor Tech., Brussels, Belgium, Aug 19, 1985) DE85010279/GAR

KEY WORDS: Nuclear reactors, Blast resistant structures, Fluid-structure interaction

The code SAFE/RAS is applied to the analysis of a new design concept for the above-core structures when subjected to the loads of a core disruptive accident. The analysis involves the determination of the postbuckling response of a thin cylinder loaded both axially and vertically. The effects of variation of cylinder thickness and fluid-structure interaction are investigated.

86-1195
Investigation of Steel Containment Buckling from Dynamic Loads
T.A. Butler, W.E. Baker, J.G. Bennett, C.D. Babcock
Los Alamos National Lab., NM
Rept. No. LA-UR-85-1285, CONF-85809-60, 21 pp (1985) (Intl. Conf. on Struc. Mech. in Reactor Tech., Brussels, Belgium, Aug 19, 1985) DE85010704/GAR

KEY WORDS: Nuclear containment structures, Steel, Base excitation, Seismic response

Buckling of free-standing nuclear steel containment buildings from dynamic base excitation was investigated in a combined experimental/numerical program. A polycarbonate scale model of a containment building was excited with scaled earthquake transients and single frequency harmonic transients to determine the peak base acceleration levels required to induce buckling. Buckling was identified using recorded signals from strain gages and accelerometers, with high-speed video records, and by audibility. Experimental results are compared with numerical results obtained using a freezing-in-time technique. The results are preliminary since several more tests are to be performed. However, the limited data obtained indicates that the freezing-in-time technique approximates the required acceleration levels reasonably well, although not conservatively. Additional experiments are described that will take containment asymmetries into account, as well as use instrumentation that will provide more accurate measures of the occurrence of buckling.

86-1196
Comparison of Test and Earthquake Response Modeling of a Nuclear Power Plant Containment Building
M.G. Srinivasan, C.A. Kot, B.J. Hsieh
Argonne National Lab., IL
Rept. No. CONF-850809-10, 7 pp (1985) (Intl. Conf. Struc. Mech. in Reactor Tech., Brussels, Belgium, Aug 19, 1985) DE85006901/GAR

KEY WORDS: Nuclear containment structures, Nuclear power plants, Seismic tests

The reactor building of a BWR plant was subjected to dynamic testing, a minor earthquake, and a strong earthquake at different times. Analytical models simulating each of these events were devised by previous investigators. A comparison of the characteristics of these models is made in this paper. The different modeling assumptions involved in the different simulation analyses restrict the validity of the models for general use and also narrow the comparison down to only a few modes. The dynamic tests successfully identified the first mode of the soil-structure system.

86-1197
Seismic Qualification of Equipment. A Summary of Findings
A.C. Heidebrecht, W.K. Tso
Atomic Energy Control Board, Ottawa, Ontario, Canada
Rept. No. INFO-95, 67 pp (Mar 1983) DE85701961/GAR

KEY WORDS: Nuclear power plants, Equipment response, Seismic response

This report describes the results of an investigation into the seismic qualification of equipment located in CANDU nuclear power plants. It is particularly concerned with the evaluation of current seismic qualification requirements, the development of a suitable methodology for the seismic qualification of safety systems, and the evaluation of seismic qualification analysis and testing procedures.

86-1198
Seismic Analysis of a Large LMFBR with Fluid-Structure Interactions
D.C. Ma
Argonne National Lab., IL
Rept. No. CONF-850809-36, 18 pp (1985) (Intl. Conf. Struc. Mech. in Reactor Tech., Brussels, Belgium, Aug 19, 1985) DE85009699/GAR

KEY WORDS: Nuclear reactors, Fluid-structure interaction, Seismic response

The seismic analysis of a large LMFBR with many internal components and structures is presented. Both vertical and horizontal seismic excitations are considered. The important hydrodynamic phenomena such as fluid-structure interaction, sloshing, fluid coupling and fluid inertia effects are included in the analysis. The results of this study are discussed in detail. Information which is useful to the design of future reactions under seismic conditions is also given.

86-1199
Seismic Interactions Between Primary Tank and Core Barrel
D.C. Ma
Argonne National Lab., IL
Rept. No. CONF-850809-39, 17 pp (1985) (Intl. Conf. Struc. Mech in Reactor Tech., Brussels, Belgium, Aug 19, 1985) DE85009707/GAR

KEY WORDS: Nuclear reactors, Fluid-structure interaction, Seismic response

A study of seismic interactions between the primary tank and core barrel is presented. The study indicates that the distance of the core barrel from the primary tank wall plays an important role in the determination of the frequencies of the primary system. When the distance between the core barrel and primary tank wall is reduced, the frequencies of the primary tank and core barrel are also reduced. Also observed is the beating phenomenon of these two frequencies. This becomes more pronounced when the difference between these two frequencies is small.

OFF-SHORE STRUCTURES

86-1200
Nonlinear Free Vibration of Fixed Off-Shore Framed Structures
A. Ragab, Chung C. Fu
Cairo Univ., Giza, Egypt
Computers Struc., 21 (6), pp 1373-1378 (1985) 4 figs, 9 refs

KEY WORDS: Off-shore structures, Framed structures, Transverse shear deformation effects, Rotatory inertia effects

The dynamical behavior of fixed off-shore framed structures is studied using the Wittrick-Williams algorithm to solve the nonlinear eigenvalue problem. The effects of shear deformation and rotary inertia as well as axial static loading are considered in this study of nonlinear free vibration. The members are assumed to be rigidly connected and the added water mass is assumed equal to the mass of the water displaced. The structural modeling is based on a two-dimensional representation of the three-dimensional tower assuming a constant dimension equal to the base length perpendicular to the plane. The distributed masses of the members in the plane of the frame are computed by summing up the structural mass, the mass of the water contained in the tube, and the mass of the water displaced. The member masses in the plane perpendicular to the frame are assumed to be lumped at the horizontal cross-brace levels. The results of the study indicated that while the first two frequencies obtained from the nonlinear and linear eigenvalue solutions agree closely, the effect of the nonlinear eigenvalue solution is significant for the higher frequencies. The results also highlight the significant effects of the axial static force in the dynamic tangent stiffness matrix in the free vibration study of the off-shore structures.

86-1201
Free Span Vibrations of Submarine Pipelines in Steady Flows — Effect of Free-Stream Turbulence on Mean Drag Coefficients
A. Trum, N.M. Anand
Univ. of Trondheim, Norway
J. Energy Resources Tech., Trans. ASME, 107 (4), pp 415-420 (Dec 1985) 6 figs, 12 refs

KEY WORDS: Off-shore structures, Pipelines, Turbulence, Fluid-induced excitation

In this paper part of the results of a laboratory study related to free span vibrations of submarine pipelines in steady and wave-induced fluid flows are summarized. Tests have been carried out using an elastically supported rigid smooth circular cylinder close to a plane smooth boundary in steady flows with turbulence intensities of 3.4, 5.5, and 9.5 percent for four cylinder gap to diameter ratios, G/D equal to 0.5, 0.75, 1.0 and 3.0. Effects of turbulence intensity on the mean drag force and vibration amplitudes are discussed.

86-1202
A Slender-Body Theory for a Rigid Pile Under Static or Low-Frequency Axial Loading
S.N.B. Fallou, C.C. Mei
Massachusetts Institute of Technology, Cambridge, MA
J. Energy Resources Tech., Trans. ASME, 107 (4), pp 433-440 (Dec 1985) 4 figs, 12 refs

KEY WORDS: Pile structures, Underwater structures, Axial excitation, Wave forces

If the seabed is modeled as a poroelastic medium, the stresses and pore pressure induced by sea waves attacking pile-supported structures can be approximately treated by a quasi-static, single-phase theory almost everywhere except near the unsealed mudline. Therefore, the theory of a pile in an elastic half-space is fundamental. A survey of literature indicated that existing theories are only numerical; the few analytical formulas are based on either intuitive argument or interpolation of numerical work. A more systematic theory is first developed here for an axially loaded pile by employing slender-body approximation to a pair of integral equations. The results are used to calculate the pore pressure in the seabed around low-frequency loading.

86-1203
Seismic Response of Underwater Members of Variable Cross Section
K. Nagaya, Y. Hai
Gunma Univ., Gunma, Japan
J. Sound Vib., 103 (1), pp 119-138 (Nov 8, 1985) 14 figs, 3 tables, 8 refs

KEY WORDS: Underwater structures, Variable cross section, Seismic response

This paper is concerned with a method for solving seismic response problems of a pile of variable cross section with a tip inertia subjected to a sea bottom seismic displacement. The analysis developed here is based on an elastodynamic theory in which the effects of the continuously distributed mass and rigidity of the pile are included. The method includes use of Fourier series expansion, the Laplace transform, the transfer matrix method and the residue theorem in order to deal with the complex seismic displacement and arbitrarily shaped piles; considerable simplification of the calculations is thus achieved. The theoretical results given are applicable to seismic response problems for a pile of arbitrary shape with a tip inertia, excited by arbitrary displacements. As an application of the present theoretical results, the dynamic response has been calculated for hollow piles of curved conical shape with a tip inertia, excited by arbitrary displacement. As an application of the present theoretical results, the dynamic response has been calculated for hollow piles of curved conical shape with tip inertias and double taper beams subjected to seismic displacements.

VEHICLE SYSTEMS

GROUND VEHICLES

86-1204
Prediction of the Effectiveness of Noise Control Treatments in Urban Rail Elevated Structures
P.J. Remington, L.E. Wittig
Bolt Beranek and Newman, Inc., Cambridge, MA
J. Acoust. Soc. Amer., 78 (6), pp 2017-2033 (Dec 1985) 19 figs, 3 tables, 10 refs

KEY WORDS: Elevated railroads, Noise control

An analytical model is presented for the generation of noise from an open tie deck elevated structure during the passage of a train. Predictions are compared with measurements before and after installation of resilient fasteners. The model is found to be reasonably accurate, predicting an A-weighted sound level reduction of approximately 2dB less than actually occurs. The analytical model is then used to estimate the noise reduction achievable through a variety of noise reduction techniques. Resilient rail fasteners seem to be the most promising technique, offering an A-weighted sound level reduction of nearly 10 dB.

86-1205
Dynamic Analysis of a Bulkhead Flat Car Underframe Structure
K.H. Chu, V.K. Garg, Y.L. Wang
Illinois Institute of Technology, Chicago, IL
Computers Struc., 21 (5), pp 1067-1077 (1985) 14 figs, 4 tables, 18 refs

KEY WORDS: Freight cars

A dynamic analysis of the underframe (U/F) structure of a 100-ton bulkhead flat car was performed. Center plate accelerations and side bearing forces were obtained from the dynamic analysis of the car system using random track irregularity inputs. The objective of this study was to investigate the effect of bulkheads on the natural frequencies and mode shaped, the maximum dynamic stresses and to modify the design of the U/F structure according to the results of the dynamic analysis. The fatigue life of the U/F structure, based on the calculated stress ranges is considered.

86-1206
Vehicle Overturning Vulnerability from Air Blast Loads
R.R. Robinson, H. Napadensky, A. Longinow
IIT Res. Inst., Annapolis, MD
10 pp (Aug 1984) (Minutes of Explosives Safety Seminar (21st), Houston, TX, Aug 28-30, 1984, pp 215-224, Vol. 1, AD-P004 826/4/GAR

KEY WORDS: Ground vehicles, Vulnerability, Air blast, Shock response

The overturning response of an armored personnel carrier to air blast loads derived from a nuclear blast environment is presented. The orientation of the vehicle is side-on to the air blast shock front. It is assumed there is no translation at the downwind wheels, i.e., the roll over point. In addition, the vehicle is assumed to behave as a rigid body. The results give the threshold nuclear environment that just causes overturning. The threshold environment is given in terms of a peak overpressure corresponding to a weapon yield. Results are presented for a range of weapon yields from 1KT to 1MT.

SHIPS

86-1207
Interactive Approximations for a Cavitating Fluid Around a Floating Structure
M.L. Rehak, F.L. DiMaggio, I.S. Sandler
Weidlinger Associates, New York, NY
Computers Struc., 21 (6), pp 1159-1175 (1985) 18 figs, 13 refs

KEY WORDS: Ships, Floating structures, Underwater explosions, Cavitation

A method is investigated for determining the response of floating structures to underwater explosions strong enough to cause bulk cavitation. In such problems the difference between the actual and free field pressures on any surface surrounding the structure and cavitated region is related to the corresponding velocity differences by a linear functional relation. In this paper, it is proposed that approximate functionals, called interactive approximations, be applied on these surfaces, called interaction horizons. In the limit, the interaction horizon can be taken as the wet surface of the structures, eliminating the consideration of fluid field equations. The technique is applied to the two-dimensional problems of a rigid rectangular structure, floating on a fluid with a bilinear constitutive relations, subjected to a plane, exponentially decaying wave having an angle of incidence. First the exact solution of the nonlinear, steady state, free field problem, including determination of the cavity, is obtained by the method of characteristics. Then the interaction problem is solved by finite differences, using both plane wave and doubly asymptotic interactive approximations, at interaction horizons and on the wet surface. When an interaction horizon is used, Lax's one-dimensional scheme is modified to discretize the fluid equations. It is found that, for this example, the plane wave approximation applied directly to the wet surface is sufficiently accurate to determine structural response.

86-1208
Numerical Modelling of Fluid-Structure and Structure-Structure Interaction in Ship Vibration
M.K. Hakala
Valtion Teknillinen Tutkimuskeskus, Espoo, Finland
Rept. No. VTT/PUB-22, ISBN-951-38-2305-9, 66 pp (1985) PB85-224921/GAR

KEY WORDS: Ships, Fluid-structure, Finite element technique

Fluid-structure and structure-structure interaction in ship vibration are analyzed and numerical calculation procedures based on the finite element method are developed. A parametric study is performed in a case of a simple model

resembling a box-like ship to reveal the relative importance of various parameters in the interaction process. The developed procedures are tested using an example structure for which experimental results are also available. The accuracy of the global-local approach and the truncation errors in the modal solution are studied.

86-1209
Analysis of Local Vibrations on Board 8200 DWT Container Ship
Xie Quan-Sheng, Zhu Qun-Chao
Ship Engrg., (3), pp 29-34 (1985) CSTA No. 623.8-85.23

KEY WORDS: Ship hulls, Cargo ships, Vibration control

This paper describes the causes of the hull structure local vibrations on the "SHANGHAI EXPRESS". Some effective measures of reducing the vibrations are suggested.

86-1210
Effect of Strut Shape on Swath Ship Motion
Y.S. Hong
David W. Taylor Naval Ship Res. and Dev. Ctr., Bethesda, MD
Rept. No. DTNSRDC-85/048, 27 pp (July 1985) AD-A157 614/9/GAR

KEY WORDS: Ships, Struts, Geometric effects, Time domain method

Three different strut shapes were investigated to determine the effect of shape on the heave motion of SWATH ships at heave resonance. A time-domain analysis was developed to include the nonlinear effect of large motion amplitude. A two-dimensional model, in which the ship forward speed is assumed to be zero, was investigated to simplify the problem. The results show that a proper choice of strut shape can reduce the ship heave motion substantially at resonance.

86-1211
Adaptive Prediction of the Motion of Marine Vehicles
E.R. Jefferys, B.S. Samra
University College, London, UK
J. Energy Resources Tech., Trans. ASME, 107 (4), pp 450-454 (Dec 1985) 4 figs, 10 refs

KEY WORDS: Ships, Wave forces, Wind-induced excitation

A predictor of the future motion of a vessel subject to random wave and wind forces, would have a variety of applications in ocean engineering. Most previous work has assumed that the wave spectrum is known and that the vessel is modeled accurately. In practice, the relevant data is difficult to measure on a maneuvering vessel and can change significantly with operating conditions. Here the application of an adaptive algorithm which predicts the future of a signal from its history is described. The predictor adapts to the signal and varies its parameters to optimize the prediction. Operating on a signal with a stationary spectrum, the predictor tends to a steady performance; if the spectrum changes, the predictor quickly adjusts to the new situation.

86-1212
Vertical Relative Motion Between Two Adjacent Platforms in Oblique Waves
C.H. Kim, M.C. Fang
Stevens Institute of Technology, Hoboken, NJ
J. Energy Resources Tech., Trans. ASME, 107 (4), pp 455-460 (Dec 1985) 7 figs, 1 table, 13 refs

KEY WORDS: Ships, Cylinders, Hydrodynamic excitation, Wave forces

The paper presents a strip theory and its correlation with experiment and analysis on the relative motions of two ships. The ships are in close proximity and in parallel position in oblique waves. The two-dimensional procedure takes account of the hydrodynamic interaction between two cylindrical bodies. It was found that the strip method is a useful technique to predict the hydrodynamically coupled motions of two ships.

AIRCRAFT

86-1213
Theoretical Appraisal of the Use of Ground-Plane Microphones for Aircraft Noise Measurements
R.C. Payne, G.F. Miller
National Physical Lab., Teddington, UK
Rept. No. NPL-AC-103, 40 pp (1984) PB85-230977/GAR

KEY WORDS: Aircraft noise, Noise measurement, Measurement techniques

The pattern of sound pressure across the plate mounted in or over the ground surface, when exposed to the noise of an over-flying aircraft, is examined theoretically. In particular, the effects of diffraction due to the impedance mis-match between the baffle and the ground surface are studied. This has been done with a view to finding the optimum arrangement for a microphone on the ground plane to measure aircraft noise, particularly that emitted from light propeller aircraft. Ranges of a number of parameters are considered and a particular arrangement is recommended which gives a close approach to a measurement of a pressure-doubled sound spectrum.

86-1214
Aircraft Cabin Noise Prediction and Optimization
R. Vaicaitis
Columbia Univ., New York, NY
Rept. No. NASA-CR-175982, 85 pp (July 1985) N85-30768/4/GAR

KEY WORDS: Aircraft noise, interior noise, Noise prediction, Optimization

Theoretical and experimental studies were conducted to determine the noise transmission into acoustic enclosures ranging from simple rectangular box models to full scale light aircraft in flight. The structural models include simple, stiffened, curved stiffened, and orthotropic panels and double wall windows. The theoretical solutions were obtained by modal analysis. Transfer matrix and finite element procedures were utilized. Good agreement between theory and experiment has been achieved. An efficient acoustic add-on treatment was developed for interior noise control in a twin aircraft.

86-1215
Effects of Propeller Rotation Direction on Airplane Interior Noise Levels
C.M. Willis, W.H. Mayes, E.F. Daniels
NASA Langley Res. Ctr., Hampton, VA
Rept. No. L-15892, NASA-TP-2444, 34 pp (July 1985) N85-30767/6/GAR

KEY WORDS: Aircraft noise, Interior noise, Propeller blades

Interior noise measurements for upsweeping and downsweeping movement of the propeller blade tips past the fuselage were made on a twin-engine airplane and on two simplified fuselage models. Changes in interior noise levels of as much as 8 dB $\times$ reversal of propeller rotation direction were measured for some configurations and test conditions.

86-1216
Doublet Strip Method for Oscillating Swept Tapered Wings in Incompressible Flow
A. Ichikawa
Civil Aviation College, Miyazaki, Japan
J. Aircraft, 22 (11), pp 1008-1012 (Nov 1985) 9 figs, 6 refs

KEY WORDS: Aircraft wings, Aerodynamic loads

An improved numerical method is developed for calculating the load distributions on oscillating swept tapered wings in incompressible flow. The integration domain is transformed into a rectangular domain, and the domain is divided into many chordwise strips. In the strip containing the control point, the proposed method properly accounts for Cauchy and logarithmic singularities. The solutions generally compared well with other lifting-surface theories, but with much smaller computational times.

86-1217
Supersonic Potential Gradient Method for the Calculation of Unsteady Aerodynamic Pressures on Harmonically Oscillating Wings
F. Zhang
Deutsche Forschungs-und Versuchsanstalt fuer Luftund Raumfahrt e.V., Goettingen, Fed. Rep. Germany
Rept. No. DFVLR-FB-85-11, 107 pp (Feb 1985) (A translation will be available as ESA-TT-930)

KEY WORDS: Aircraft wings, Aerodynamic loads

A method for calculating unsteady aerodynamic pressure distribution on harmonically oscillating three-dimensional wings in supersonic flow based on the velocity potential, the Jones-Appa gradient method and the application of an integral variable substitution to evaluate the aerodynamic influence functions was developed. The method simplifies the computation and reduces computing time at low supersonic Mach numbers and high reduced frequencies. Investigations on typical wing configurations confirm accuracy.

86-1218
Flutter Clearance Tests on a Transavia PL-12/T-400 Skyfarmer
A. Goldman, S. Galea

Aeronautical Res. Labs., Melbourne, Australia
Rept. No. ARL/STRUC-TM-400, 66 pp (Mar 1985) AD-A157 212/2/GAR

KEY WORDS: Aircraft, Flutter, Vibration tests

A ground resonance test and subsequent flight tests were conducted on a Transavia T-400 Skyfarmer. The natural modes and frequencies of vibration were measured in the ground tests, and monitored during flight tests. Attempts were made to induce flutter. The results of these tests are presented.

86-1219
Verification of Calculation Methods for Unsteady Airloads in the Precipitation of Transonic Flutter
R.J. Zwaan
National Aerospace Lab., Amsterdam, Netherlands
Rept. No. NLR-MP-84016-U, B8562384, 11 pp (Feb 24, 1984) N85-31027/4/GAR

KEY WORDS: Aircraft wings, Flutter, Aerodynamic loads

Engineering methods to calculate unsteady airloads on wings in transonic flow were applied in flutter calculations for a semispan flutter model of a supercritical wing. A verification was performed by comparing flutter characteristics, and the prediction of transonic dips in the flutter boundaries. When applied complementary, the methods produce useful results.

86-1220
Flutter and Divergence Aeroelastic Characteristics for Composite Forward Swept Cantilevered Wing
I. Lottati
Technion--Israel Institute of Technology, Haifa, Israel
J. Aircraft, 22 (11), pp 1001-1007 (Nov 1985) 10 figs, 18 refs

KEY WORDS: Aircraft wings, Flutter

An analytical investigation was conducted to determine the aeroelastic flutter and divergence behavior of a cantilevered, composite, forward swept rectangular wing. The influence due to the variation of the bending-torsion stiffness coupling of the tailored wing on the flutter and divergence critical dynamic pressure is analyzed. Flutter and divergence velocities were obtained by using an optimization procedure that solves exactly the coupled bending-torsion equations for a cantilevered swept wing. The results indicate that the flutter and divergent of a fixed-root wing involve a compromise, since the bending-torsion stiffness that maximized the flutter velocity tend to minimize the divergent speed and vice versa.

86-1221
Fatigue Crack Propagation in Mirage IIIO Wing Main Spar Specimens and the Effects of Spectrum Truncation on Life
J.Y. Mann, R.A. Pell, A.S. Machin
Aeronautical Res. Labs., Melbourne, Australia
Rept. No. ARL/STRUC-R-405, 56 pp (July 1984) AD-A156 952/4/GAR

KEY WORDS: Aircraft wings, Fatigue tests, Crack propagation

As part of an investigation into the life extension and safe operation of the Mirage IIIO aircraft wings, a fatigue testing program and extensive fractographic examination was undertaken on specimens representing the critical section of the spar.

86-1222
The Numerical Computation of Aircraft Response to Arbitrary Vertical Gust Distributions
Jiguang An, Zhen Yan, Chuanren Qui, Wenbo Zhou
The Chinese Aerodynamic Res. and Dev. Ctr., Mianyang, China
J. Aircraft, 22 (11), pp 988-992 (Nov 1985) 13 figs, 10 refs

KEY WORDS: Aircraft, Wind-induced excitation, Fluid-induced excitation

The partial results of a subsonic longitudinal response that has been used in some practical design work are summarized. The aircraft gust response consists of three modes: dynamic, control and elastic structure. In the control response mode, the responses of both the pilot and the gust alleviator have been considered. The type of gust may be either discrete or continuous with an arbitrary velocity distribution. The aircraft are also arbitrary and include conventional and canard configurations. Some comparisons of the results obtained here with those of analytical methods have been made and it is found that they agree quite well.

86-1223
Impact Dynamics Research on Composite Transport Structures
H.D. Carden
NASA Langley Res. Ctr., Hampton, VA
Rept. No. NASA-TM-86391, 25 pp (Mar 1985) N85-30367/5/GAR

KEY WORDS: Crash research (aircraft), Composite materials, Energy absorption

The experimental and analytical efforts being undertaken to investigate the response of composite and aluminum structures under crash loading conditions were reviewed. A Boeing 720 airplane was used in the controlled-impact demonstration test. Energy absorption of composite materials, the tearing of fuselage skin panels, the friction and abrasion behavior of composite skins, and the crushing behavior and dynamic response of composite beams were among the topics addressed.

86-1224
Advanced Rotor Analysis Methods for the Aerodynamics of Vortex-Blade Interactions in Hover
J.M. Summa
Analytical Methods, Inc., Bellevue, WA
Vertica, 9 (4), pp 331-343 (1985) 13 figs, 1 table, 17 refs

KEY WORDS: Helicopters, Propeller blades, Vortex shedding

The work discussed in this report has shown that the complete hovering rotor wake geometry, including the inner sheet, can be predicted without the constraints or empiricisms of a prescribed wake. Moreover, the calculated wakes for some modern rotors violate the usual hypothesis in prescribed wake methods of a weak linear inner sheet and a single rolled-up tip vortex. When coupled with a lifting-surface method, this relaxed wake procedure allows for the accurate analysis of rotor performance at proper collective settings. Finally, the application of a surface singularity method developed for rotors has demonstrated the capability of accurately computing blade surface pressures very near the rotor tip edge.

86-1225
Response of a Rotorcraft Model with Damping Non-Linearities
B.H. Tongue
Georgia Institute of Technology, Atlanta, Georgia
J. Sound Vib., 103 (2), pp 211-224 (Nov 22, 1985) 7 figs, 31 refs

KEY WORDS: Helicopters, Propellers, Self-excited vibrations, Ground resonance

The linearized equations of motion of a helicopter in contact with the ground have solutions which can be linearly stable or unstable, depending on the system parameters. The present study includes physical non-linearities in the helicopter model. The present analysis applies to helicopters having fully articulated rotors.

86-1226
Standardized Fatigue Loading Sequences for Helicopter Rotor (Helix and Felix) Part 1. Background and Fatigue Evaluation
P.R. Edwards, J. Darts
Royal Aircraft Establishment, Farnborough, UK
Rept. No. RAE-TR-84084, DRIC-BR-95787, 114 pp (Aug 1984) AD-A156 621/5/GAR

KEY WORDS: Helicopters, Propellers, Fatigue tests, Crack propagation

A standard loading sequence is a variable amplitude repeated sequence of peak and trough loads to be applied in fatigue and crack propagation tests. Each standard represents loading on a particular class of engineering structure. Two such existing standards are FALSTAFF (Fighter Aircraft Loading STAndard For Fatigue evaluation) and TWIST (Transport Wing STandard), which represent loading on fighter and transport aircraft wings respectively. Their development has arisen from the fact that often, life prediction methods are not accurate enough to predict fatigue lives or crack rates adequately under service (variable amplitude) loading conditions. Therefore, when making a fatigue assessment of, for instance, a new detail, fastening system, or method of life improvement, variable amplitude loading has to be used. This report describes the derivation and fatigue assessment of two loading standards for the fatigue evaluation of helicopter rotor materials and components.

86-1227
Standardized Fatigue Loading Sequences for Helicopter Rotors (Helix and Felix) Part 2. Final Definition of Helix and Felix
P.R. Edwards, J. Darts
Royal Aircraft Establishment, Farnborough, UK
Rept. No. RAE-TR-84085, DRIC-BR-95846, 124 pp (Aug 1984) AD-A156 622/3/GAR

KEY WORDS: Helicopters, Propellers, Fatigue life, Standards and codes

This report defines two loading standards for the fatigue evaluation of helicopter rotor materials and components. They were developed as a collaborative study between West Germany, the Netherlands, and UK. Details of the contributing organizations are given in Appendix A. The new loading standards follow the earlier TWIST (Transport Wing STandard), and FALSTAFF (Fighter Aircraft Loading STAndard For Fatigue evaluation). After the tradition of these earlier loading sequences, the new loading standards have been given identifying names. For these the origin of the work helicopter (helix-spiral, pteronwing from the Greek) has provided a convenient basis. The new standards are called: Helix - loading standard for "hinged" and articulated rotors; Felix - loading standard for fixed or semi-rigid rotors. This report defines the final form of the two standards, statistical content according to different counting methods and full details of their method of generation.

86-1228
Application of Modern Structural Optimization to Vibration Reduction in Rotorcraft
P. Friedmann
Univ. of California, Los Angeles, CA
Vertica, 9 (4), pp 363-376 (1985) 10 figs, 1 table, 42 refs

KEY WORDS: Helicopters, Vibration control, Optimization

This paper explores a number of techniques which are capable of reducing vibration levels in rotorcraft by redistributing the mass and stiffness properties of the structure. First, vibration reduction in the rotor is considered by using formal structural optimization for ensuring optimal frequency placement. Two cases are considered: in the first case aeroelastic constraints are enforced and vibration levels are minimized in forward flight. Next, vibration reduction in the fuselage is considered and the various methods available for vibration reduction by local structural modification are reviewed. The feasibility of combining local structural modification with modern structural optimization is discussed and some extensions of previous research are suggested.

86-1229
Fixed Gain and Adaptive Techniques for Rotorcraft Vibration Control
R.H. Roy, H.A. Saberi, R.A. Walker
Integrated Systems, Inc., Palo Alto, CA
Rept. No. T47130, NASA-CR-177344, 127 pp (May 1985) N85-33111/4/GAR

KEY WORDS: Helicopters, Vibration control

The results of an analysis effort performed to demonstrate the feasibility of employing approximate dynamical models and frequency shaped cost functional control law design techniques for helicopter vibration suppression are presented. Both fixed gain and adaptive control designs based on linear second order dynamical models were implements in a detailed Rotor Systems Research Aircraft (RSRA) simulation to validate these active vibration suppression control laws. Approximate models of fuselage flexibility were included in the RSRA simulation in order to more accurately characterize the structural dynamics. The results for both the fixed gain and adaptive approaches are promising and provide a foundation for pursuing further validation in more extensive simulation studies and in wind tunnel and/or flight tests.

86-1230
Low-Speed Stability Characteristics of a Helicopter with a Sling Load
B.L. Nagabhushan
Goodyear Aerospace Corp., Akron, OH
Vertica, 9 (4), pp 345-361 (1985) 19 figs, 1 table, 12 refs

KEY WORDS: Helicopters, Sling loads

The low-speed stability characteristics of a conventional helicopter with an external sling load on a single-point suspension are investigated using an 18th order dynamic model of the two-body system. Nonlinear equations of motion which describe the 6 d.f. rigid body motion of the helicopter, including its rotor dynamics, coupled with both longitudinal and lateral dynamics of the sling load have been derived and linearized for this purpose. Significant differences, including instability and cross coupling in the associated pendulous motion of the sling load and the inherent oscillatory motions of the helicopter, were found between operation with a short and a long sling cable. These results are illustrated here by an example helicopter and its sling load.

86-1231
Flutter Clearance of the Schweizer 1-36 Deep-Stall Sailplane
M.W. Kehoe, J.F. Ellison

NASA Ames Res. Ctr., Moffett Field, CA
Rept. No. REPT-85136, NASA-TM-85917, 78 pp (Aug 1985) N85-33118/9/GAR

KEY WORDS: Gliders, Flutter, Aeroelasticity

A Schweizer 1-36 sailplane was modified for a controlled, deep-stall flight program. This modification allowed the horizontal stabilizer to pivot as much as 70 deg leading edge down. Ground vibration and flutter testing were accomplished on the sailplane with the horizontal stabilizer in the normal flight and deep stall flight position. Test results indicated satisfactory damping levels and trends for the structural modes of the sailplane. The modified sailplane was demonstrated to be free of aeroelastic instabilities of 83 KEAS with the horizontal stabilizer in the normal flight position and to 39 KEAS with the horizontal stabilizers in the deep-stall flight position. The flight envelope was adequate for the controlled, deep-stall flight experiments.

MISSILES AND SPACECRAFT

86-1232
Dynamics and Control of Large Flexible Space Structures
P.M. Bainum, A.S.S.R. Reddy, C.M. Diarra, S. Ananthakrishnan
Howard Univ., Washington, DC
Rept. No. NASA-CR-175986, 94 pp (June 1985) N85-29996/4/GAR

KEY WORDS: Spacecraft, Equations of motion

A development of the in-plane open loop rotational equations of motion for the proposed *Spacecraft Control Laboratory Experiment* (SCOLE) in orbit configuration is presented based on an Eulerian formulation. The mast is considered to be a flexible beam connected to the (rigid) shuttle and the reflector. Frequencies and mode shapes are obtained for the mast vibrational appendage modes for different boundary conditions based on continuum approaches and also preliminary results are obtained using a finite element representation of the mast reflector system.

86-1233
Accuracy of Modelling the Dynamics of Large Space Structures
C.M. Diarra, P.M. Bainum
Howard Univ., Washington, D.C.
11 pp (Oct 1985) N85-29995/6/GAR

KEY WORDS: Spacecraft, Mathematical models, Continuous parameter method

Proposed space missions will require large scale, light weight, space based structural systems. Large space structure technology (LSST) systems will have to accommodate (among others): ocean data systems; electronic mail systems; large multibeam antenna systems; and, space based solar power systems. The structures are to be delivered into orbit by the space shuttle. Because of their inherent size, modeling techniques and scaling algorithms must be developed so that system performance can be predicted accurately prior to launch and assembly. A computational algorithm was developed to evaluate the coefficients of the various coupling terms in the equations of motion as applied to the finite element model of the Hoop/Column.

86-1234
Structural Dynamics Model and Response of the Deployable Reference Configuration Space Station
J.M. Housner
NASA Langley Res. Ctr., Hampton, VA
Rept. No. NASA-TM-86386, 93 pp (May 1985) N85-33539/6/GAR

KEY WORDS: Space stations, Mathematical models

The analytical models and results of a structural dynamics investigation of the reference initial operation and evolutionary configurations of the nine foot bay space station are presented.

BIOLOGICAL SYSTEMS

HUMAN

86-1235
Evaluation of Vibrational Performance of Light Weight Wooden Floors: State-of-the Art and Recommendations for Future Research
Y.H. Chui, V.C. Kearley, I. Smith
Timber Res. and Development Assn., High Wycombe, UK
Rept. No. RR-3/85, 22 pp (1985) PB85-235422/GAR

KEY WORDS: Human response, Floors, Vibration excitation, Vibration damping

Vibrations of light-weight wooden floors is usually considered as a serviceability problem relating to human discomfort. Traditional design on the basis of static deflection of a single beam has in some instances been found to produce floors with unacceptable dynamic performance. The report reviews methods for evaluation of human response to floor vibrations, 'dynamic design' and 'dynamic analysis' methods for floors, and damping characteristics of floors. Based on the studies of previous works, recommendations are made for future research.

MECHANICAL COMPONENTS

ABSORBERS AND ISOLATORS

86-1236
Auto and Truck Suspension Systems. June 1970-November 1985 (Citations form the Engineering Index Data Base)
NTIS, Springfield, VA
212 pp (Nov 1985) PB85-872299/GAR

KEY WORDS: Suspension systems (vehicles), Automobiles, Trucks, Shock absorbers, Bibliographies

This bibliography contains citations concerning the effects of suspension systems on the performance of motor vehicles. Topics include shock absorbers, steering stability, and load leveling, as well as the characteristics of both leaf and coil springs. Materials considerations such as fatigue and wear are also discussed. This updated bibliography contains 331 citations, 22 of which are new entries to the previous edition.

86-1237
Dynamic Analysis of a Unidirectional Periodic Isolator, Consisting of Identical Masses and Intermediate Distributed Resilient Blocks
A.F. Vakakis
Univ. of Patras, Patras, Greece
J. Sound Vib., 103 (1), pp 25-33 (Nov 8, 1985) 5 figs, 12 refs

KEY WORDS: Isolators, Elastomers, Internal damping

An analytical procedure for the dynamic analysis of the unidirectional periodic isolator, consisting of n concentrated masses and n intermediate arbitrary blocks is developed. Complex polynomials depending on the four pole parameters of the mounts and on the frequency of excitation are introduced, to express analytical forms for the impedances and transmissibilities of the general system. By means of these polynomials, the frequency equation of the undamped isolator can be derived directly, for free or fixed boundary conditions. Application of the method was made with isolators consisting of masses and distributed elements of rubber with internal damping.

86-1238
Use of Pneumatic Active Suspensions to Improve Lateral Rail Vehicle Ride Quality
J.K. Hedrick, D. Cho, R. Barietta, L.C. Chen
Massachusetts Inst. of Tech., Cambridge, MA
Rept. No. DOT/OST/P34-85/020, 148 pp (Aug 1984) PB85-226884/GAR

KEY WORDS: Active isolation, Pneumatic springs, Suspension systems (vehicles), Railroad trains

The report summarizes the work completed during the final phase of a three year project. The goal of the project was to develop improved suspension concepts for high speed ground vehicles. In particular in those applications where restricted operating envelopes limit the improvements that can be made by conventional means. The application area chosen for the project was the lateral ride quality of intercity passenger trains.

86-1239
Current State of Knowledge on Structural Control
A.M. Reinhorn, G.D. Manolis
State Univ. of New York, Buffalo, NY
Shock Vib. Dig., 17 (10),. pp 7-16 (Oct 1985) 1 table, 92 refs

KEY WORDS: Active vibration control, Semi-active vibration, Vibration control, Reviews

Structures occasionally experience extreme loads, especially during earthquakes or in a high wind environment. Furthermore, it is now becoming possible to deploy large and flexible structures in space. In both cases the response of the structure must be controlled within certain bounds dictated by serviceability. The problem is

energy dissipation from or energy input to the structure through external mechanisms. Traditionally, energy has been dissipated through damping. Passive control devices have been used that basically supplement the damping characteristics of a structure. Semi-active and active control devices have recently been introduced. They promise a more efficient use of the resources available for control and improved accuracy in controlling the response of a structure.

86-1240
Seismic Response of Light Internal Equipment in Base-Isolated Structures
J.M. Kelly, Hsiang-Chuan Tsai
Univ. of California, Berkeley, CA
Earthquake Engrg. Struc. Dynam., 13 (6), pp 711-732 (Nov/Dec 1985) 14 figs, 3 tables, 10 refs

KEY WORDS: Base isolation, Seismic design, Buildings, Equipment-structure interaction

The seismic response of light secondary systems in a building is dependent on the response of the primary structural system to the seismic ground motion with the result that very high accelerations can be induced in such secondary systems. This response can be reduced through the use of aseismic base isolation which is a design strategy whereby the entire building can be decoupled from the damaging horizontal components of seismic ground motion by the use of some form of isolation system. The paper presents a theoretical analysis of the response of light equipment in isolated structures and a parallel experimental program. Both of which show that the use of base isolation can not only attenuate the response of the primary structural system but also reduce the response of secondary systems. Thus, the design of equipment and piping in a base-isolated building is very much simpler than that for a conventionally founded structure: inelastic response and equipment-structure interaction need not be considered and multiple support response analysis is rendered unnecessary. The results of both the analysis and the tests show that base isolation is a very effective method for the seismic protection of light equipment items in buildings.

86-1241
Nonlinear Seismic Analysis of a Large Sodium Pump
S.N. Huang
Hanford Engrg. Development Lab., Richland, WA Rept. No. HEDL-SA-3261-FP, Conf-850670-20, 16 pp (1985) (ASME Pressure Vessel & Piping Div. Conf., New Orleans, LA, June 24, 1985) DE85014001/GAR

KEY WORDS: Seismic isolation, Pumps, Nuclear reactor components, Seismic analysis

The bearings and seismic bumpers used in a large sodium pump of a typical breeder reactor plant may need to be characterized by nonlinear springs and gaps. Then, nonlinear seismic analysis utilizing the time-history method is an effective way to predict the pump behaviors during seismic events, especially at those bearing and seismic bumper areas. In this study, synthesized time histories were developed based on specified seismic response spectra. A nonlinear seismic analysis was then conducted and results were compared with those obtained by linear seismic analysis using the response spectrum method. In contrast to some previous nonlinear analysis trends, the bearing impact forces predicted by nonlinear analysis were higher than those obtained by the response spectrum method. This might be due to the larger gaps and stiffer bearing supports used in this specific pump. However, at location distant from the impact source, the nonlinear seismic analysis has predicted slightly less responses than those obtained by linear seismic analysis. The seismically induced bearing impact forces were used to study the friction induced thermal stresses on the hydrostatic bearing and to predict the coastdown time of the pump. Results and discussions are presented.

BLADES

86-1242
A Measurement Method to Evaluate Fluid Force on Blades
Hiroshi Ishii, Noriaki Hagiwara
Hitachi Ltd., Ibaraki, Japan
Bull. JSME, 28 (242) pp 1741-1748 (Aug 1985) 15 figs, 5 refs

KEY WORDS: Blades, Fluid-induced excitation, Force measurement, Transfer functions

The purpose of this study was to establish a measurement method for the fluid force acting on axial turbo machines. The method aims to evaluate the fluid forces as divided into two components, i.e., exciting force and damping

force. This method is found to be satisfactory in comparison with other ordinary methods of estimating the fluid force acting on a column test piece in a wind tunnel. According to the results of a test using an axial compressor model with flat blades, the method can quantitatively predict the fluid force acting on rotating blades.

86-1243
Theoretical and Experimental Aspects of the Dynamics of Horizontal Axis Wind Turbines
G.H. Silas, T. Cioara
The Polytechnic Inst., Timisoara, Romania
Rev. Roumaine Sci. Tech., Mecanique Appl., 30 (2/3), pp 193-202 (Mar-June 1985)

KEY WORDS: Blades, Wind Turbines, Vibration tests, Computer programs, Mode shapes

This paper presents some theoretical and experimental aspects of the dynamics of horizontal axis wind turbines. A general formulation of the differential equations of the motion of the flexible blade, the most important component of the turbine, is given. In order to identify the mathematical model of the blade an experimental stand for vibratory testing of the flexible blade coupled with a rigid body substructure is used. With the implementation of some algorithms into computer programs mode shapes and model parameters of the flexible blade are obtained.

86-1244
Simulation of the Effects of Shock Wave Passing on a Turbine Rotor Blade
D.J. Doorly, M.L.G. Oldfield
Oxford Univ., England
J. Engrg. Gas Turbines Power, Trans. ASME, 107 (4), pp 998-1006 (Oct 1985) 14 figs, 30 refs

KEY WORDS: Turbine blades, Shock waves, Wind tunnel testing

The unsteady effects of shock waves and wakes shed by the nozzle guide vane row on the flow over a downstream turbine rotor have been simulated in a transient cascade tunnel. At conditions representative of engine flow, both wakes and shock waves are shown to cause transient turbulent patches to develop in an otherwise laminar (suction-surface) boundary layer. The simulation technique employed, coupled with very high-frequency heat transfer and pressure measurements, and flow visualization, allowed the transition initiated by isolated wakes and shock waves to be studied in detail. On the profile tested, the comparatively weak shock waves considered do not produce significant effects by direct shock-boundary layer interaction. Instead, the shock initiates a leading edge separation, which subsequently collapses, leaving a turbulent patch that is convected downstream. Effects of combined wake-and shock wave-passing at high frequency are also reported.

86-1245
The Vibratory Response of Frictionally Constrained Gas Turbine Engine Blades
Chia-Hsiang Menq
Ph.D. Thesis, Carnegie-Mellon Univ., 190 pp (1985) DA8513691

KEY WORDS: Turbine blades, Coulomb friction

This thesis investigates the forced response of frictionally constrained gas turbine engine blades. The main objective is to determine the optimal normal load to be applied at the friction interface for maximum reduction in resonant vibratory stresses in blades. A systematic approach is developed for performing dynamic analyses of frictionally constrained structures, in which linear structures are represented by receptances and friction joints are characterized by nonlinear impedances. The method of harmonic balance, which is widely used in the design of nonlinear dynamic systems, is augmented to solve this particular class of problems. Using this method, the structural and the friction interface calculations are carried out independently and then the results are used to perform the nonlinear part of the dynamic analysis. Lastly, the methodology is extended to solve problems with multiple friction joints, such as a shrouded fan stage. This approach is important since it can be directly applied to gas turbine engine design.

86-1246
Unsteady Aerodynamic Characteristics of a Blade in Pitching Oscillation with Flow Separation
Ichiro Fujimoto, Hideo Tanaka, Susumu Ishii, Kazuo Yamaguchi
Univ. of Tokyo, Tokyo, Japan
Bull. JSME, 28 (242), pp 1610-1617 (Aug 1985) 17 figs, 16 refs

KEY WORDS: Blades, Aerodynamic coefficients

Unsteady aerodynamic characteristics are investigated. Chordwise distributions of unsteady pressures obtained on an airfoil oscillating in pitch

with a separation bubble which shows a nature of so-called short bubble are analyzed. The mechanism of energy transfer between an oscillating blade and an airflow is made clear by utilizing the chordwise distribution of energy transfer, and the effects of the separation bubble on flutter characteristics are clarified. In addition, the validity of potential flow theory is examined and a simple model of a blade oscillation considering the angle of attack relative to main flow is applied to explaining the effects of the location of pitching center.

86-1247
Unsteady Aerodynamic Characteristics of a Blade in Pitching Oscillation with Flow Separation
Ichiro Fujimoto, Hideo Tanaka, Susumu Ishii, Kazuo Yamaguchi
Univ. of Tokyo, Tokyo, Japan
Bull. JSME, 28 (242), pp 1618-1625 (Aug 1985) 17 figs, 10 refs

KEY WORDS: Blades, Aerodynamic characteristics

Unsteady aerodynamic characteristics are investigated in detail by analyzing chordwise aspects of energy transfer between a blade oscillating in pitch and an air flow at the leading edge stall condition. The simple model of blade oscillation developed in the first report for the case of an attached flow is also applicable to the case of the leading edge stall. In addition, semi-empirical improvements are added to the wake model in Shinohara's theoretical analysis which is based on the free streamline theory and the method of singularity. Then, the validity of this theoretical analysis is confirmed by a comparison with experiments.

86-1248
Unsteady Aerodynamic Characteristics of a Blade in Pitching Oscillation with Flow Separation
Ichiro Fujimoto, Hideo Tanaka, Susumu Ishii, Kazuo Yamaguchi
Univ. of Tokyo, Tokyo, Japan
Bull. JSME, 28 (242), pp 1626-1633 (Aug 1985) 13 figs, 6 refs

KEY WORDS: Blades, Aerodynamic characteristics

Unsteady stall characteristics of a blade oscillating in pitch at an angle of attack near stall region are examined including a dynamic hysteresis phenomenon of stalling in the process of changing the reduced frequency. Effects of this dynamic hysteresis phenomenon on unsteady aerodynamic characteristics of an oscillating blade are made clear in a bi-stable region where either state of a fully separated flow or an attached (strictly speaking, partially separated) flow persists continuously during the blade oscillation depending upon the history of frequency variation. It is also found that the characteristics of aerodynamic damping are affected remarkably by the dynamic hysteresis phenomenon depending upon the location of pitching center.

86-1249
Unsteady Aerodynamic and Heat Transfer Processes in a Transonic Turbine Stage
D.A. Ashworth, J.E. LaGraff, D.L. Schultz, K.J. Grindrod
Univ. of Oxford, England
J. Engrg. Gas Turbines Power, Trans. ASME, 107 (4), pp 1022-1030 (Oct 1985) 23 figs, 10 refs

KEY WORDS: Turbine rotors, Aerodynamic loads

The effect of the interaction of the wake from a nozzle guide vane with the rotor may be simulated in part by means of a stationary rotor and a moving wake system. This technique is applied to a transonic rotor blade cascade, and the unsteady measurements of surface pressure and heat transfer rate are compared with baseline data obtained without the wake interaction. The wake-rotor interaction results in a change in inlet incidence angle and this effect is also examined in the steady-state case. It is found that the shock waves from the moving wake system have a major effect on the instantaneous heat transfer rates.

BEARINGS

86-1250
Starvation in Dynamically Loaded Flexible Short Journal Bearings
L. van der Tempel, H. Moes, R. Bosma
SWDiesel, Amsterdam, The Netherlands
J. Trib., Trans. ASME, 107 (4), pp 516-521 (Oct 1985) 10 figs, 15 refs

KEY WORDS: Journal bearings, Hydrodynamic lubrication

A starvation model is incorporated in a previously presented numerical method for calculating

film thicknesses in flexible short journal bearings under dynamic load. The system of elastohydrodynamic integro-differential equations is coupled with continuity equations for the lubricant, considering central circumferential oil grooves and a constant supply pressure. An important application of this method is the connecting rod bearing in medium speed combustion engines. Results for several groove geometries are compared with those for a fully flooded bearing.

86-1251
Dynamically Loaded Journal Bearings: A Finite Element Treatment for Rigid and Elastic Surfaces
G.A. LaBouff, J.F. Booker
Cornell Univ., Ithaca, NY
J. Trib., Trans. ASME, 107 (4), pp 505-515 (Oct 1985) 11 figs, 27 refs

KEY WORDS: Journal bearings, Hydrodynamic lubrication, Finite element technique

Hydrodynamic lubrication of dynamically loaded journal bearings with both rigid and flexible housing is treated by a unified computational procedure based on the finite element method. Numerical examples show effects of mesh density and housing flexibility under steady and periodic loading.

86-1252
Generation and Transmission of Vibration in Plain Cylindrical Bearings. Part 2. Experiment
L.V. Embling, C.J. Jenkins, P. Meyer
Admiralty Marine Technology Establishment, Teddington, UK
Rept. No. AMTE(N)/R84009, DRIC-BR-95691, 67 pp (Sept 1984) AD-A156 577/9/GAR

KEY WORDS: Cylindrical bearings, Vibration transfer

The vibration transmission characteristics of hydrodynamic bearings have been investigated at frequencies well above the out of balance frequency. Part 1 of this report developed theories to predict the linear transfer functions of bearings and to examine the effects of nonlinearities in modulating the response to external forces. This part of the report describes an experimental investigation on a bearing test rig aimed at validating the theories. It is concluded that bearings are not always rigid to vibration, the frequency range over which the rigidity applies being determined by the bearing parameters. Transfer functions across the bearing in the direction of the applied force are reciprocal. The bearing can introduce modulation in the response to a single-frequency force.

86-1253
Effect of Speed and Press Fit on Fatigue Life of Roller-Bearing Inner-Race Contact
H.H. Coe, E.V. Zaretsky
NASA Lewis Res. Ctr., Cleveland, OH
Rept. No. E-2476, NASA-TP-2496, 13 pp (July 1985) N85-31511/7/GAR

KEY WORDS: Roller bearings, Fatigue life, Contact stresses

An analysis was performed to determine the effects of inner ring speed and press fit on the rolling element fatigue life of a roller bearing inner race contact. The effects of the resultant hoop and radial stresses on the principal stresses were considered. The maximum shear stresses below the Hertzian contact were determined for different conditions of inner ring speed, load, and geometry and were applied to a conventional ring life analysis. The race contact fatigue life was reduced by more than 90 percent for some conditions when speed and press fit were considered. The depth of the maximum shear stress remained virtually unchanged.

86-1254
Performance Characteristics of Large Scale Tilting-pad Journal Bearings
H. Hashimoto, S. Wada, T. Marukawa
Tokai Univ., Kanagawa, Japan
Bull. JSME, 28 (242), pp 1761-1767 (Aug 1985) 10 figs, 6 refs

KEY WORDS: Tilt pad bearings, Sommerfeld number, Stiffness coefficients, Damping coefficients, Unbalanced mass response

Performance characteristics of large scale tilting-pad journal bearings are examined theoretically and experimentally. Applying a turbulent lubrication equation considering pad deformations and geometrical preload of pad to 2-pads journal bearings, the static and dynamic characteristics of bearings such as Sommerfeld numbers, spring and damping coefficients and unbalance responses of rotor and journal vibrations are obtained. The theoretical results of static characteristics are compared with the experimental ones. It is concluded that pad deformations and geometrical preload or pad have significant

effects on the bearing performances under turbulent lubrication conditions. The theoretical results agree well with the experimental ones.

GEARS

86-1255
Dynamic Torsional Analysis of Gear Train System
O. Sato, H. Shimojima, S. Inano
Tokyo Inst. of Technology, Meguro-ku, Tokyo, Japan
Bull. JSME, 28 (242), pp 1756-1760 (Aug 1985) 13 figs, 3 refs

KEY WORDS: Gears, Torsional response

Equations of motion of a flexible multi-shaft gear train system are derived in consideration of torsion of axes, gear tooth stiffness, backlash and characteristics of driving source. Then input signal is sinusoidal and loads are dry friction, viscous friction and inertia force, dynamic characteristics of a 3-shaft system are analyzed theoretically. It is investigated experimentally.

86-1256
Study on Bending Fatigue Strength of Helical Gears
S. Oda, T. Koide, M. Mizune
Tottori Univ., Tottori, Japan
Bull. JSME, 28 (244), pp 2429-2433 (Oct 1985) 8 figs, 12 refs

KEY WORDS: Helical gears, Flexural vibrations, Fatigue life, Fatigue tests

This paper presents a study on the effect of load variation on the bending fatigue strength of helical gears. A bending fatigue testing machine for cylindrical gears controlled by a micro computer was developed. The bending fatigue test of helical gears were carried out under a uniform cyclic load and a varying load which had the load spectrum of normal distribution. Various cumulative fatigue damage rules (Miner's rule, modified Miner's rule and VDI-Richtlinien 2151) were compared.

86-1257
Dynamic Behavior of Thin-rimmed Helical Gears with Various Web Arrangements
S. Oda, T. Koide, K. Miyachika
Tottori Univ., Tottori, Japan
Bull. JSME, 28 (244), pp 2434-2441 (Oct 1985) 13 figs, 7 refs

KEY WORDS: Helical gears, Flexural vibrations, Natural frequencies

This paper presents a study on dynamic behavior of thin-rimmed helical gears with various web arrangements. Natural frequencies of flexural vibration of gear body were measured and compared with the calculated results by Mindlin's method. The relations between these natural frequencies and spectra of circumferential, radial and axial vibrations were investigated. The circumferential, radial and axial vibration accelerations and the root stresses were measured under different running conditions by using a gear testing machine of a power absorbing type. On the basis of these results the effects of web arrangements on vibration and dynamic load were clarified to a considerable extent.

LINKAGES

86-1258
Control of Shaking Force and Shaking Moment in Link Mechanism
Bo Liang Guan, Takeshi Furuhashi, Nobuyoshi Morita
East China Inst. of Textile Science and Technology
Bull. JSME, 28 (243), pp 2078-2083 (Sept 1985) 6 figs, 5 refs

KEY WORDS: Four-bar mechanisms, Balancing techniques, Vibration control

The control of the shaking force and the shaking moment in a link mechanism consists in obtaining the specified shaking force and the specified shaking moment without changing the motion of mechanism for the required mass parameters of each link. In this paper, a new approach to this problem is presented. As an example, a crank lever mechanism is controlled using the methods. The waveforms of the shaking force and the shaking moment can be controlled and their magnitudes can be decreased as the specified ones.

86-1259
A Linearized Lumped Parameter Approach to Vibration and Stress Analysis of Elastic Linkages
G.N. Sandor, Xirong Zhuang

Univ. of Florida, Gainesville, Fl
Mech. Mach. Theory, 20 (5), pp 427-437 (1985) 9 figs, 30 refs

KEY WORDS: Linkages, Lumped mass method, Finite difference method, Rotatory inertia effects

Nonlinear equations of motion resulting from the limped-mass modeling of mechanism links are linearized and decoupled by using the concept of kinematic influence coefficients. Effect of rotatory inertia of elements and end masses of moving links is investigated. Equations of motion are solved by way of the central finite difference method. The model is applied to a planar four-bar linkage corresponding to an actual mechanism that has been examined experimentally and analyzed by nonlinear lumped parameter method. The results show that the error due to linearization is small and that rotatory inertia has significant effect on the elastic response of the mechanism.

SEALS

86-1260
Friction and Axial Force/Displacement Characteristics of Elastomer Seals in Water
R. Wensel, B. Botnam, H. Gentili, I. Constantinescu
Atomic Energy of Canada Ltd., Chalk River, Ontario, Canada
Lubric. Engrg., 41 (9), pp 550-555 (Sept 1985) 9 figs, 2 refs

KEY WORDS: Seals, Elastomers, Axial force, Friction

To optimize the performance of end-face seals as used in nuclear generating station main coolant pumps, it is important that the forces transmitted to the flexibly mounted sealing ring by its elastomer seal be known. Reduction of the forces by design is also highly desirable. These forces, the result of inevitable angular and axial movements of a seal ring relative to its shaft or housing, can have both stiffness (elastic) and damping (nonelastic friction and hysteresis) components. Tests are described and data are presented that characterize and quantify the axial force/displacement and frictional behavior of elastomer seals in pressurized water systems. An assessment is made of the effects of pressure, seal size and shape, squeeze, sliding speed, water temperature, and shaft displacement/time characteristics. The frictional behavior observed differs greatly from that described in O-ring seal handbooks.

STRUCTURAL COMPONENTS

CABLES

86-1261
The Dynamics of Translating Cables
M.S. Triantafyllou
Massachusetts Institute of Technology, Cambridge, MA
J. Sound Vib., 103 (2), pp 171-182 (Nov 22, 1985) 8 figs, 15 refs

KEY WORDS: Cables, Catenaries, Translational response

The dynamics of a translating catenary are studied. The static and linearized dynamic governing equations are derived along the local tangential and normal directions and it is shown that in this form two simpler equations can be derived and solved asymptotically for both small and large sag cables, horizontal or inclined. For small sag cables the solutions of one of the asymptotic equations undergo fundamental changes for specific values of the elastic stiffness, inclination angle, sag-to-span ratio and speed of translation resulting in strong mode interactions.

86-1262
Vortex-induced Vibrations of Marine Cables and Structures
O.M. Griffin
Naval Res. Lab., Washington, DC
Rept. No. NRL-5600, 34 pp (June 19, 1985) AD-A157 481/3/GAR

KEY WORDS: Cables, Underwater structures, Vortex-induced vibration, Fluid-induced excitation

The dynamic analysis of marine structures and cable systems has become increasingly important in order to predict stress distributions and operational lifetimes in hostile ocean environments. The amplitudes of vortex-induced vibration for a cylindrical structure such as a riser or pipeline in water are an order of magnitude greater than for a similar structure in air. The small mass ratio (structure to displace fluid) in water produces small values of the reduced damping which in turn result in the relatively large limiting vibration amplitudes shown in this report. Risers, platform mooring cables and other long, slender structures often are subjected to spanwise nonuniform shear currents. The response of long cylinders in nonuniform flows cannot be pre-

dicted accurately in many cases using existing methods which were originally developed for uniform flows. Several examples are given to illustrate these estimates. The vortex-induced hydrodynamic drag forces on vibrating structures in water are amplified substantially above the corresponding case of a structure at rest. This drag amplification has been measured in several extensive experiments and reaches 250 percent at the largest amplitudes of crossflow displacement. The available experimental results for circular cylindrical members are summarized and put to use in several example calculations.

BEAMS

86-1263
The Effects of Elastic Stops and Inelastic Restrainers on Vibrating Beam-Like Structures
A.M. Fathi
Ph.D. Thesis, The Univ. of Manitoba, Canada (1985)

KEY WORDS: Beams, Flexural vibrations, Impact excitation

An approximate technique is developed to determine the flexural response typical of many practical vibroimpact applications. The technique is shown to significantly reduce computational effort while largely preserving accuracy. However, accuracy can be improved by selectively combining the approximate technique with a purely numerical approach to enhance the details of important contact forces. The ensuing computational requirements, although increased somewhat, are still sufficiently small to permit the use of a desk-top computer. Problems associated with a user-friendly presentation of the dynamic interactions between a structure and stop are outlined. The possibility of the fine detail associated with chatter gaining prominence may be assessed from priori information by employing a newly developed energy criterion. A very computationally economical approach is formulated later to predict the maximum impact forces which are important from a design point of view. The main novelty in the latter approach lies in the effective use of non-dimensional vibroimpact parameters obtained from the equations of motion. These parameters allow subsequent results to be merely extrapolated from any one previously computed case. The computational savings are potentially tremendous in design situations where many compute runs are usually needed. A comprehensive study is also conducted to complement previous experimental work and assess the effectiveness of inelastic restrainers. The theoretical model is based upon a finite element approach and dynamic condensation is introduced to reduce computational effort.

86-1264
Exact Bernoulli-Euler Dynamic Stiffness Matrix for a Range of Tapered Beams
J.R. Banerjee, F.W. Williams
Univ. of Wales, Cardiff, Wales, UK
Intl. J. Numer. Methods Engrg., 21 (12), pp 2289-2302 (Dec 1985) 5 figs, 2 tables, 35 refs

KEY WORDS: Beams, Variable cross section, Bernoulli-Euler method, Dynamic stiffness, Matrix methods

Bernoulli-Euler theory and Bessel functions are used to obtain explicit expressions for the exact dynamic stiffnesses for axial, torsional and flexural vibrations of any beam which is tapered. Numerical checks give better than seven-figure agreement with the stiffnesses obtained by extrapolation from stepped beams with 400 and 500 uniform elements A procedure is given for calculating the number of natural frequencies exceeded by any trial frequency when the ends of the member are clamped. This enables an existing algorithm to be used to obtain the natural frequencies of structures which contain tapered members.

86-1265
Fatigue and Cracking Behavior of Partially Prestressed Concrete Members
M. A.-H. El Shahawi
Ph.D. Thesis, Queen's Univ. at Kingston, Canada (1985)

KEY WORDS: Beams, Prestressed concrete, Fatigue Life, Fracture properties

The fatigue and cracking behavior of partially prestressed concrete beams was investigated in a series of tests on twelve bonded post-tensioned T-beams. The beams were simply supported, and had the same overall dimensions, and were designed for the same flexural strength. The main parameter in the investigations was the degree of prestress. Eight beams were tested in fatigue, while the remaining four companion beams were tested under static loading. In the fatigue tests, five beams were subjected to a constant load cycle, while the remaining three beams were subjected to cumulative damage tests. All beams were initially cracked before the application of repeated loading.

86-1266
Dynamic Response of a Flexible Space Beam
M.F. Card, M.S. Anderson, J.E. Walz
NASA Langley Res. Ctr., Hampton, VA
Rept. No. NASA-TM-86441, 19 pp (May 1985) N85-30368/3/GAR

KEY WORDS: Beams, Spacecraft

Dynamic response of a candidate flexible beam for a space experiment on control of flexible structures is investigated. Studies of natural frequencies reveal a beam length in which torsion and bending frequencies virtually coincide. Eccentric tip mass causes small shifts in natural frequencies but introduces coupled torsional/bending mode shapes. Transient response studies indicate significant effects on tip responses of low damping and first bending mode excitation at higher frequencies. Steady state response suggest displacement and acceleration measurements could be made up to 5 to 12 Hz for the actuator forces/torques assumed.

CYLINDERS

86-1267
On the Force and Vortex Shedding on a Circular Cylinder from Subcritical up to Transcritical Reynolds Numbers
Tsutomu Adachi, Kazuo Matsuuchi, Satoshi Matsuda, Tatsuo Kawai
Univ. of Tsukuba, Ibaraki, Japan
Bull. JSME, 28 (243), pp 1906-1909 (Sept 1985) 8 figs, 10 refs

KEY WORDS: Circular cylinders, Vortex shedding, Wind tunnel testing

Pressure distributions and vortex shedding were measured in a cryogenic wind tunnel from subcritical up to transcritical Reynolds numbers and Mach numbers up to 0.3 without changing experimental arrangement. Drag coefficients were calculated using pressure distributions. Pressure distributions and drag coefficients show characteristic changes for subcritical, lower transition, critical, upper transition and transcritical Reynolds numbers respectively. The pressure distributions and spectra of velocity fluctuations are presented for several characteristic values of Reynolds numbers. Results are also compared with those of other authors.

86-1268
Modal Solutions, Symmetry Properties, and Orthogonality Conditions for Elastic Waves in Cylinders
J. McKenna, P.G. Simpkins
AT&T Bell Laboratories, Murray Hill, New Jersey
J. Acoust. Soc. Amer., 78 (5), pp 1675-1683 (Nov 1985) 18 refs

KEY WORDS: Modal analysis, Elastic waves, Wave propagation, Cylinders,

Modal analysis is used to study the elastic wave motions in a rod of circular cross section. Two particular situations are considered: the semi-infinite rod with an arbitrary load applied at one end, and the finite length rod with arbitrary loads at each end. Interest in this problem was stimulated by experimental observations of flexural waves generated in high-strength optical fibers during tensile testing. The use of modal methods to examine pulse propagation in elastic cylinders has been limited by the complexity of the analysis. Here, a number of symmetry relationships are established which reduce the complexity and simplify the analysis. Orthogonality properties of the modes are derived and are used to obtain general solutions of the wave equation in the frequency domain. These solutions occur only when particular types of mixed boundary conditions are applied to the ends. It is believed that the solutions for the finite rod problem are new. The results generalize the Pochhammer-Chree theory.

COLUMNS

86-1269
Regions of Instability of Vibrations of Columns Subjected to Periodic Axial Force
Tadashi Kotera
Kobe Univ., Kobe, Japan
Bull. JSME, 28 (243), pp 2056-2063 (Sept 1985) 8 figs, 6 refs

KEY WORDS: Columns, Periodic excitation, Axial excitation, Stability

Regions of instability of vibrations of columns subjected to periodic axial force are determined by approximation of characteristic equations with an infinite determinant. Approximation by a determinant of order three or four gives sufficiently accurate regions of instability which cannot be determined by the Hsu formula. A more accurate numerical method also is shown.

86-1270
Dynamic Stability of Pretwisted Columns Under Periodic Axial Loads
Z. Celep
Technical Univ., Maslak, Istanbul, Turkey
J. Sound Vib., 103 (1), pp 35-42 (Nov 8, 1985) 4 figs, 11 refs

KEY WORDS: Columns, Axial excitation

This paper deals with the parametric instability of pretwisted columns subjected to static and periodic axial loads. The governing equations of the problem are reduced to time domain by applying Galerkin's method. The instability regions are determined with the procedure proposed by Hsu. The analysis includes free vibration and static buckling of the column as special cases. Although the method is quite general, numerical calculations are carried out only for a simply supported column. Free vibration frequencies, static buckling loads and the coefficients of the instability regions are obtained for various values of the pretwisting angle and those of the cross sectional rigidity ratio of the columns.

FRAMES AND ARCHES

86-1271
Impact Tests on Frames and Elastic-Plastic Solutions
J.M. Mosquera, H. Kolsky, P.S. Symonds
Brown Univ., Providence, RI
ASCE J. Engrg. Mech., 111 (11), pp 1380-1401 (Nov 1985) 19 figs, 3 tables, 22 refs

KEY WORDS: Frames, Pulse excitation, Elastic plastic properties, Experimental data, Finite element technique

Experimental and analytical work is described in further investigation of a simplified method for estimating final and peak deflection amplitudes of a pulse loaded structure. The method includes effects of elastic response interacting with plastic deformation, but gains simplicity by treating them in artificially separated stages. An initial elastic response stage is followed by a wholly plastic (i.e. rigid plastic) stage, which in turn is followed by elastic vibrations. Experiments were performed in which portal frames of aluminum alloy and mild steel were impacted at the midpoint of one column by masses projected at various speeds. The contact force pulse was recorded and used as input data for analyses. In addition to the simplified elastic-plastic (SEP) method, numerical analyses were carried out by a finite element code (furnishing nominally "exact" solutions) and by approach assuming rigid-plastic behavior for the entire response. It is found that with the relatively long pulses produced in the present impact experiments, elastic-plastic interactions may be critically important. Consideration of strain rate sensitive plastic flow in the steel frames requires special treatment. Reasonably good agreement with results of tests and finite element calculations was given by the SEP method, whereas a rigid-plastic solution grossly underestimated final deflections in certain cases.

86-1272
Dynamic Optimization of Framed Structures
E.A. Sadek
Cairo Univ., Egypt
Computers Struc., 21 (6), pp 1313-1323 (1985) 8 figs, 7 refs

KEY WORDS: Framed structures, Optimization

An analytical procedure for the determination of the least weight structure which satisfies a specific frequency requirement plus upper and lower bounds on the design variables is presented. The design algorithm is an iterative solution of the Kuhn-Tucker optimality criterion. The procedure is to modify an existing design to first obtain the correct structural frequency and then, while the frequency is held constant, to minimize the weight. This is accomplished using gradient equations derived in matrix notation for direct application to the finite element method of analysis.

PANELS

86-1273
Panel Vibration Damping Due to Sound-Absorbing Liners
A. Trochidis
Univ. of Thessaloniki, Thessaloniki, Greece
J. Acoust. Soc. Amer., 78 (6), pp 2058-2060 (Dec 1985) 2 figs, 3 refs

KEY WORDS: Panels, Vibration damping, Acoustic linings

A mechanism of panel vibration damping due to the addition of absorbing liners is discussed. An

expression for the loss factor associated with the described damping mechanism is derived. It predicts satisfactorily not only the observed damping but also its dependence on the vibration frequency, the acoustical impedance of the sound-absorptive material, and the separation distance between the panel and absorbing liner surfaces.

PLATES

86-1274
Elastic Buckling and Flexural Vibration of Variable Thickness Annular Plates Under Uniform In-plane Forces Along the Inner and/or Outer Edges
O. Majima, K. Hayashi
Sophia Univ., Tokyo, Japan
Bull. JSME, 28 (243), pp 1830-1835 (Sept 1985) 5 figs, 13 refs

KEY WORDS: Plates, Flexural vibration, Variable cross section, Galerkin method

The problems of elastic buckling and flexural vibration of variable thickness annular plates have been analyzed by the Galerkin method. Eigenfunctions of natural vibration of a constant thickness annular plate without in-plane force have been adopted as admissible functions. Numerical calculations were carried out for the annular plates of linearly varying thickness under uniform in-plane force along the inner and/or outer edges. Both symmetric and asymmetric deformations were taken into consideration in this procedure.

86-1275
Numerical Approximation of Sound Radiation of Impact-Excited Plates (Näherungsweise Berechnung der Schallabstrahlung von stoßartig angeregten Platten)
W. Heitkämper
Institut für Technische Akustik, TU Berlin
Acustica, 58 (3), pp 141-148 (Aug 1985) 7 figs, 10 refs (in German)

KEY WORDS: Plates, Impact excitation, Sound waves, Wave radiation

A numerical approximation for the spectrum of a force acting on a plate during the impact of a sphere is derived with regard to elastic deformation at the contact zone. The sound radiation of the impact-excited plate is characterized by a pulse radiated from the point of impact with a time history given by the plate velocity at this point and by the radiation of the annular propagating, dispersing bending wave. The radiated sound energy can be estimated by using a diagram. By varying the material parameters in a proper way, it is possible to minimize the radiated energy.

86-1276
A Method for Solving Free Vibration Problems of Three-Layered Plates with Arbitrary Shape
K. Poltorak, K. Nagaya
Warsaw Technical Univ., Warsaw, Poland
J. Acoust. Soc. Amer., 78 (6), pp 2042-2048 (Dec 1985) 7 figs, 10 tables, 15 refs

KEY WORDS: Plates, Layered materials, Vibration response

This paper deals with a method for solving free vibration problems of three-layered isotropic plates of arbitrary shape with clamped edges. The direct solution of the Yan and Dowell equation of motion, in terms of Bessel functions, is found. The boundary problem is solved by means of the Fourier expansion collocation method. Nondimensional frequency parameters for circular, elliptical, square, and triangular plates with clamped edges are calculated for a wide range of dimension ratios and two typical material configurations. The validity of the method is also discussed.

86-1277
Optimum Thickness Distribution of Unconstrained Viscoelastic Damping Layer Treatments for Plates
A. Yildiz, K. Stevens
Technical Univ. of Istanbul, Istanbul, Turkey
J. Sound Vib., 103 (2), pp 183-199 (Nov 22, 1985) 3 figs, 2 tables, 25 refs

KEY WORDS: Plates, Viscoelastic damping, Layered materials

This paper concerns the optimum thickness distribution of unconstrained viscoelastic damping layer treatments for plates. The system loss factor is expressed in terms of the mechanical properties of the plate and damping layer and the layer/plate thickness ratio. Optimum distributions of the thickness ratio that maximize the system loss factor are obtained through sequential unconstrained minimization techniques. Re-

sults are presented for both simply-supported and edge-fixed rectangular plates with aspect ratios of 1·0 to 4·0. These results indicate that the system loss factor can be increased by as much as 100%, or more, by optimizing the thickness distribution of the damping treatment. Also revealed are the regions of the plate where added damping treatments are most effective.

86-1278
Nonlinear Free Bending Vibrations of Plates
B.A. Ovunc
Univ. of Southwestern Louisiana, Lafayette, Louisiana
Computers Struc., 21 (5), pp 887-891 (1985) 2 figs, 29 refs

KEY WORDS: Plates, Flexural vibrations

A general solution for the Helmholtz differential equations is obtained in the complex domain and applied to the nonlinear, free, bending vibrations of plates. The analysis is based on the decoupled nonlinear von Karman field equations by Berger assumption for the large deformations of plates. The decoupled differential equation in terms of the deflections functions is a fourth order Helmholtz differential equations. Its solution, called the dynamic deflections function, is obtained in the complex domain by means of newly defined first and second kind and modified Bessel functions. The dynamic deflection function can be applied to any plates having any shape and any boundary condition under any arbitrary dynamic loads. For plates with smooth boundary, the parameters of the dynamic deflection function are determined from the boundary of plates and the initial conditions of the vibrations. The analyses of plates with piece-wise smooth boundaries are obtained on the mapped planes. The nonlinear, free vibration of circular plates are investigated by the dynamic deflection function. The effect of stretching on the natural circular frequencies are illustrated.

86-1279
Research on Dynamic Behavior of Composite and Sandwich Plates - IV
C.W. Bert
The Univ. of Oklahoma, Norman, OK
Shock Vib. Dig., 17 (11), pp 3-15 (Nov 1985) 1 table, 163 refs

KEY WORDS: Plates, Composite structures, Sandwich structures

This paper comprises a survey of the literature concerning the dynamic behavior of plate-type structural elements of either composite material or sandwich construction. Papers from mid-1982 through early 1985 and several references published late in 1981 are reviewed. Emphasis is given to transverse impact and subsequent damage, environmental aspects, linear and nonlinear analysis, and design (including aeroelastic tailoring). Configurations include rectangularly and cylindrically orthotropic, and laminated this plates; thick plates; and sandwich plates.

86-1280
Vibration and Stability of Elastically Supported Circular Plates Under Conservative and Non-Conservative Loads
M. Sasaki, S. Chonan
Tohoku Univ., Sendai, Japan
J. Sound Vib., 103 (1), pp 99-108 (Nov 8, 1985) 7 figs, 7 refs

KEY WORDS: Circular plates, Elastic supports, Natural frequencies, Flutter

This paper deals with the vibration and stability of circular plates elastically restrained against translation and rotation along concentric intermediate circles as well as at the outer edge. The plate is subjected to a horizontal or tangential radial load at the periphery. Both axisymmetric and non-axisymmetric vibrations are considered. It is assumed that the plate is thin, elastic, and isotropic. The solutions are obtained in terms of Bessel functions for both the complete and annular plate sections. The effect of the support stiffnesses on the plate natural frequency and the divergence and flutter instability loads are studied in detail.

86-1281
Nonlinear Axisymmetric Static and Transient Analysis of Orthotropic Thin Tapered Circular Plates
P.C. Dumir, K.N. Khatri
Indian Institute of Technology, New Delhi, India
Computers Struc., 21 (5), PP 1001-1012 (1985) 11 figs, 5 tables, 12 refs

KEY WORDS: Circular plates, Transient response, Variable cross section

This study deals with the geometrically nonlinear axisymmetric static and transient analysis of cylindrically orthotropic elastic thin tapered circular plates subjected to uniformly distributed

and discrete central loads. Differential equations in terms of transverse displacement and stress function have been employed. The displacement and stress function are expanded in finite power series. The orthogonal point collocation method in space domain and Newmark-beta scheme in time domain have been used. Step function dynamic loads are considered. Static and dynamic results have been presented for isotropic and orthotropic immovable clamped and simply supported plates with linearly varying thickness for three values of taper ratios; the effect of varying thickness has been investigated. A simple approximate method is used to predict the maximum dynamic response to step load from the results for static loads and is found to yield sufficiently accurate results.

86-1282
Effect of an Elastic Foundation on Axisymmetric Vibrations of Polar Orthotropic Annular Plates of Variable Thickness
U.S. Gupta, R. Lal, C.P. Verma
Univ. of Roorkee, Roorkee, India
J. Sound Vib., 103 (2), pp 159-169 (Nov 22, 1985) 4 figs, 5 tables, 15 refs

KEY WORDS: Annular plates, Variable cross section, Elastic foundations, Axisymmetric vibrations

Free axisymmetric vibrations of a polar orthotropic annular plate of linearly varying thickness resting on an elastic foundation of Winkler type are studied on the basis of classical theory of plates. The fourth order linear differential equation with variable coefficients governing the motion is solved by using the quintic spline interpolation technique for three different combinations of boundary conditions. The effect of the elastic foundation together with the orthotropy on the natural frequencies of vibration is illustrated for different values of the radii ratio and the thickness variation parameter for the first three modes of vibration. Transverse displacements and moments are presented for a specified plate. The validity of the spline technique is demonstrated by presenting a comparison of present results with those available in the literature.

86-1283
Vibration of Triangular Plates of Variable Thickness
S. Mirza, M. Bijlani
Univ. of Ottawa, Canada
Computers Struc., 21 (6), pp 1129-1135 (1985) 5 figs, 6 tables, 14 refs

KEY WORDS: Cantilever plates, Variable cross section, Natural frequencies, Mode shapes, Finite element technique

The problem of natural frequencies and mode shapes of cantilevered triangular plates with variable thickness and arbitrary planform is solved using the finite element technique. This is done for various combinations of four non-dimensional geometric parameters, namely, the aspect ratio, the two thickness ratios along the two coordinate directions and the sweepback angle. The frequencies for the various cases are tabulated and a few typical mode shapes have been presented graphically.

86-1284
Large Amplitude Vibrations of Rectangular Plates with Non-Uniform Elastic Edge Supports
J. Ramachandran, K. Bhaskar
Indian Institute of Technology, Madras, India
J. Sound Vib., 103 (2), pp 153-158 (Nov 22, 1985) 2 figs, 11 refs

KEY WORDS: Rectangular plates, Boundary condition effects, Elastic restraints

Large amplitude vibrations of a rectangular plate with parabolically varying rotational constraints on two opposite edges are studied. The problem has been solved by both Berger's approach and the more rigorous von Karman approach. Galerkin's method is used to obtain an ordinary differential equation in the modal function. The solution is given in terms of elliptic functions.

86-1285
Coupled Thickness-shear and Thickness-twist Vibrations of Unelectroded AT-cut Quartz Plates
H.F. Tiersten, R.C. Smythe
Rensselaer Polytechnic Institute, Troy, NY
J. Acoust. Soc. Amer., 78 (5), pp 1684-1689 (Nov 1985) 2 figs, 4 tables, 10 refs

KEY WORDS: Rectangular plates, Quartz, Resonant frequencies

The equation of coupled thickness-shear and thickness-twist vibrations for rotated Y-cut quartz plates is applied in the analysis of unelectroded rectangular and circular AT-cut quartz plates with free edges. In the case of the rectangular

plate, the appropriate edge conditions are found and the solutions are obtained. In the case of the circular plate, the two coefficients appearing in the planar differential operator are written as a sum of an isotropic part plus a deviation. The eigensolutions for the nearby isotropic case are found and the resonant frequencies for the actual anisotropic case are obtained from the equation for the perturbation of the eigenfrequency from the isotropic solution. For the circular plate, the results have been compared with measurements of the fundamental and the third harmonic overtone, and the agreement is quite good.

86-1286
Nonlinear Effects in the Coupled Response of Tiles Bonded to a Plate
M. El-Raheb, P. Wagner
California Institute of Technology, Pasadena, CA
J. Acoust. Soc. Amer., 78 (5), pp 1690-1698 (Nov 1985) 9 figs, 3 tables, 6 refs

KEY WORDS: Bounded structures, Plates, Tiles, Impulse response, Coupled response

The coupled response to a large impulse on tiles bonded to a finite plate is studied. The analysis includes geometric nonlinearity born from boundary restraint in the plane, which stiffens the plate transversely. It also includes material nonlinearities born from plasticity of the plate's material and from properties of a polymer bond including memory and dissipation. The equations of motion are solved by the Galerkin method using linearized eigenfunctions of the system as trial functions. A strip of plate which is one tile wide is modeled.

86-1287
A Technique for Measurement of Structure-Borne Intensity in Plates
E.G. Williams, H.D. Dardy, R.G. Fink
Naval Research Laboratory, Washington, DC
J. Acoust. Soc. Amer., 78 (6), pp 2061-2068 (Dec 1985) 11 figs, 2 tables, 10 refs

KEY WORDS: Plates, Acoustic intensity method, Structure born noise, Measurement techniques

A measurement technique to determine the structure-borne intensity (power flow) in a point-driven, fluid-loaded, homogeneous thin plate is demonstrated. This intensity is uniquely determined from a knowledge of the normal velocity of the surface of a sinusoidally driven plate. A noncontact method is presented which uses a scanning hydrophone to measure the pressure in a plane very close to the source. It is shown how this pressure measurement is sufficient to compute the two-dimensional structural intensity vector inside the plate. This technique is called SIMAP for Structural Intensity from the Measurement of Acoustic Pressure. Uses of the structural intensity vectors to compute the power injected into the plate from a point drive are shown. Independent measurement of injected mechanical power is shown to be in close agreement. SIMAP, which is an outgrowth of near-field acoustical holography (NAH), also provides the normal acoustic intensity radiated into the medium from the same pressure measurement. A comparison of the structure-borne intensity with this normal acoustic intensity indicates that structural intensity is much more accurate in locating the real source than the acoustic intensity, the latter often failing completely. The examples given in this paper are for an underwater source, but the technique applies without modification to plate sources in air.

SHELLS

86-1288
Ovalling Oscillations of Thin Circular Cylindrical Shells in Cross Flow — An Experimental Study
A. Panesar, D.J. Johns
Loughborough Univ. of Technology, Loughborough, England
J. Sound Vib., 103 (2), pp 201-209 (Nov 22, 1985) 6 figs, 19 refs

KEY WORDS: Cylindrical shells, Fluid-induced excitation, Vortex shedding

Experiments have been made to study the effect of a splitter-plate on the oscillation amplitudes, wake fluctuations and unsteady surface pressures of a shell undergoing ovalling oscillations in a cross flow in a wind tunnel. The results suggest that there is no major effect of the splitter-plate on these quantities and that periodic vortex shedding is probably the case of the ovalling.

86-1289
Free Vibration of Toroidal Shells
T. Kosawada, K. Suzuki, S. Takahashi
Yamagata Univ., Yamagata, Japan
Bull. JSME, 28 (243), pp 2041-2047 (Sept 1985) 5 figs, 3 tables, 12 refs

KEY WORDS: Toroidal shells, Natural frequencies, Mode shapes, Lagrange equations

In this paper, the free vibrations of toroidal shells with circular cross section are analyzed by using a thin shell theory. The equations of motion and the boundary conditions are derived from the stationary conditions of the Lagrangian of the toroidal shell. The equations of motion are solved exactly by a power series expansion and then natural frequencies and mode shapes are obtained. Effects of various parameters upon natural frequencies are clarified in a discussion of numerical results. The frequencies obtained by this analytical method are compared with those by other approximate methods and the validities of the present exact solution are confirmed.

PIPES AND TUBES

86-1290
Response of Bayonet-type Heat Exchangers to Sinusoidal Flow Rate Changes of Large Amplitude
I. Todo
Yokohama National Univ., Yokohama, Japan
Bull. JSME, 28 (243), pp 2084-2091 (Sept 1985) 7 figs, 6 refs

KEY WORDS: Heat exchangers, Tube arrays, Fluid-induced excitation, Periodic excitation

A computational method is presented for obtaining the steady-state temperature responses of bayonet-type heat exchangers subject to sinusoidal flow rate changes of large amplitude. The frequency-and amplitude-dependent describing functions between the input sinusoidal flow rate changes and the fundamental component of the steady-state response of the outlet temperature of tube-side or shell-side fluid are also derived. Numerical examples are given and the effects of the amplitude of the flow rate changes on the frequency responses are shown.

86-1291
Acoustic Resonances in Cylinder Bundles Oscillating in a Compressible Fluid
W.H. Lin, A.C. Raptis
Argonne National Lab., IL
Rept. No. CONF-850648-1, 19 pp (Dec 1984) (Symposium on Fluid/Structure Interaction, New Orleans, LA, June 23, 1985) DE85004066/GAR

KEY WORDS: Cylinders, Tube arrays, Submerged structures, Fluid-structure interaction, Acoustic resonances

This paper deals with an analytical study on acoustic resonances of elastic oscillations of a group of parallel, circular, thin cylinders in an unbounded volume of barotropic, compressible, inviscid fluid.

86-1292
Experimental Study on Impact/Fretting Wear in Heat Exchanger Tubes
J.H. Cha, M.W. Wambsganss, J.A. Jendrzejczyk
Argonne National Lab., IL
Rept. No. ANL-85-38, 56 pp (Apr 1985) DE85014597/GAR

KEY WORDS: Tube arrays, Heat exchangers

A data bank of field experiences with heat exchanger tube vibration reveals numerous cases of tube failures at, or near, the baffle. The objective of this study is to provide qualitative impact/fretting wear information for heat exchanger tubes through the performance of a series of tests involving the pertinent parameters. The test apparatus consists of a cantilevered tube with a simulated tube support plate at the free end. Tube vibration is induced by an electromagnetic exciter to simulate the flow-induced tube motion occurring in a real heat exchanger at the tube/tube support plate interface. Tests are conducted in air, water, and oil, all at room temperature. Wear rate increases significantly with the magnitude of the impact force between the tube and its support plate; the degree and trend of the wear rates are highly dependent on the mechanical and metallurgical properties of the tube/support material combination; the rate of impact/fretting wear decreases with increasing frequency. An empirical impact/fretting wear results.

86-1293
Transient Responses of Fluid Lines
T. Muto, K. Takahashi
Faculty of Engrg., Yanagido, Gifushi, Japan
Bull. JSME, 28 (244), pp 2325-2331 (Oct 1985) 7 figs, 1 table, 6 refs

KEY WORDS: Pipelines, Transient response, Viscosity effects

Transient responses to sudden changes in pressure or flow rate is both single pipeline and series pipelines are theoretically studied under open-end and closed-end condition. A fundamental equation used in this analysis is the one for fluid line model in which the frequency-dependent effect

of viscosity is taken into consideration. It is confirmed that the theoretical results well agree with experimental ones obtained under various system conditions and parameters.

86-1294
Conclusion and Summary Report on Physical Benchmarking of Piping Systems
P. Bezler, M. Subudhi, S. Shteyngart, Y.K. Wang
Brookhaven National Lab., Upton, NY
Rept. No. BNL-NUREG-51897, 103 pp (June 1985) NUREG/CR-4291/GAR

KEY WORDS: Pipelines, Damping coefficients

Physical benchmark evaluations were used to assess the accuracy and adequacy of the analysis methods and assumptions used in typical piping qualification evaluations. Physical benchmark evaluations have been completed for six systems involving both laboratory and in situ tested piping. In each evaluation elastic finite element methods were used to predict the time history response of a system for which physical test results were available. In the analytical simulations the measured support excitations and the measured damping properties were used as input and the acceleration and displacement response of piping interior points were predicted as output. The linear analysis methods were found to provide reasonable estimates of system response. For a near linear system and using conservative estimates for system damping, a good correlation of response traces and acceptable estimates of response peaks can be expected. Using realistic estimates of uniform system damping, large underestimates of peak response components were observed and deviations of 100% or greater should be expected.

86-1295
Analysis of Pressure Wave Transients and Seismic Response in LMFBR Piping Systems Using the SHAPS Code
W.R. Zeuch, C.Y. Wang
Argonne National Lab., IL
Rept. No. CONF-850809-37, 16 pp (1985) (Intl. Conf. on Struc. Mech. in Reactor Tech., Brussels, Belgium, Aug 19, 1985) DE85009698/GAR

KEY WORDS: Pipelines, Seismic response, Computer programs

The paper presents some of the current capabilities of the three-dimensional piping code SHAPS and demonstrates their usefulness in handling analyses encountered in typical LMFBR studies. Several examples demonstrate the utility of the SHAPS code for problems involving fluid-structure interactions and seismic-related events occurring in three-dimensional piping networks. Results of two studies of pressure wave propagation demonstrate the dynamic coupling of pipes and elbows producing global motion and rigorous treatment of physical quantities such as changes in density, pressure, and strain energy. Results of the seismic analysis demonstrate the capability of SHAPS to handle dynamic structural response within a piping network over an extended transient period of several seconds. Variation in dominant stress frequencies and global translational frequencies were easily handled with the code.

DUCTS

86-1296
Application of the Time Dependent Finite Difference Theory to the Study of Sound and Vibration Interactions in Ducts
A. Cabelli
Commonwealth Scientific and Industrial Research Organization, Melbourne, Australia
J. Sound Vib., 103 (1), pp 13-23 (Nov 8, 1985) 6 figs, 13 refs

KEY WORDS: Ducts, Sound waves, Acoustic excitation, Time-dependent parameters, Finite difference technique

The time dependent finite difference theory is extended to the solution of the acoustic wave equation in rectangular ducts when acoustic/-structural interactions are allowed at a duct wall. The treatment of the boundary condition which describes the coupling is examined. The stability of the procedure is studied and found to depend on the nature of this coupling. The convergence of solutions is discussed as a function of the discretization of the solution domain, particularly at frequencies approaching resonance.

86-1297
Sound-Insulating Enclosures
G. Kurtze, K. Mueller
Karlsruhe Univ., Fed. Rep. Germany
Rept. No. BMFT-FB-HA-85-5, 59 pp (Mar 1985) N85-31925/9/GAR (in German; English summary)

KEY WORDS: Acoustic absorption, Acoustic linings, Enclosures

Sound-absorbing linings of enclosures were investigated in order to determine the most economical form. Different forms of enclosures were studied, varying the type of absorptive material, the thickness of the layer, and the size of the absorbent-lined area. It is shown that the guidelines of the investigated enclosure forms contain large safety reserves. The investigation of the requirements for sound-absorbing lining of enclosures leads to more economical ways of lining simple enclosures.

BUILDING COMPONENTS

86-1298
Seismic Floor Spectra by Mode Acceleration Approach
M.P. Singh, A.M. Sharma
Virginia Polytechnic Institute and State Univ., Blacksburg, VA
ASCE J. Engrg. Mech., 111 (11), pp 1402-1419 (Nov 1985) 4 figs, 1 table, 22 refs

KEY WORDS: Floors, Seismic response spectra, Mode acceleration method

The truncation of the high frequency modes, so commonly used in dynamic structural analysis, sometimes can cause significant errors in the calculated response; this is caused by the so-called *missing mass effect*. Such mode truncations can also affect the accuracy of floor spectra generated for stiff structural systems, and also for floors close to the base in even not so stiff structural systems, especially if the mode displacement methods are employed in the analysis. However, this problem due to mode truncation can be alleviated and virtually removed by employing the mode acceleration formulation in the analysis. Here, a direct response spectrum approach for generation of floor response spectra has been developed on the basis of the mode acceleration formulation and random vibration principles. As seismic input, this approach requires the relative acceleration spectra in lieu of the pseudo-acceleration spectra -- so commonly used with the mode displacement approaches. Because the relative spectrum values become very small for frequencies higher than the highest frequency component in the design ground motion, such high structural frequencies need not be considered in the analysis. Numerical results demonstrating the effectiveness of the proposed new approach are presented.

DYNAMIC ENVIRONMENT

ACOUSTIC EXCITATION

86-1299
Measured Acoustic Properties of Variable and Low Density Bulk Absorbers
M.D. Dahl, E.J. Rice
NASA Lewis Res. Ctr., Cleveland, OH
Rept. No. E-2633, NASA-TM-87065, 18 pp (1985) (ASME Winter Annual Meeting, Miami Beach, FL, Nov 17-21, 1985) N85-30770/0/GAR

KEY WORDS: Acoustic absorption, Experimental data

Experimental data were taken to determine the acoustic absorbing properties of uniform low density and layered variable density samples using a bulk absorber. In the layered variable density case, the bulk absorber was packed such that the lowest density layer began at the surface of the sample and progressed to higher density layers deeper inside. The samples were placed in a rectangular duct and measurements were taken using the two microphone method. The data were used to calculate specific acoustic impedances and normal incidence absorption coefficients. Results showed that for uniform density samples the absorption coefficient at low frequencies decreased with increasing density and resonances occurred in the absorption coefficient curve at lower densities.

86-1300
The Approximation of Pressure Waveforms of Impact Sound Radiation from Clamped Circular Plates of Various Thicknesses
Toshio Takahagi, Mikio Nakai
Osaka Industrial Univ., Osaka, Japan
J. Acoust. Soc. Amer., 78 (6), pp 2049-2057 (Dec 1985) 12 figs, 2 tables, 10 refs

KEY WORDS: Impact noise, Noise generation, Plates, Rotatory inertia effects, Transverse shear deformation effects

The purpose of this paper is to investigate the mechanism of impact noise generation, in order to reduce noise at its source. A fundamental model, the case of a ball striking a clamped circular plate, was studied. In the experiments, the effects of plate thickness and observation distance on sound pressure were observed. In the theoretical analysis, the rotary inertia of the

plate, shear deformation, and the air reaction of the radiated sound were considered. The impact force history was assumed to be a triangular pulse, since it was determined by three parameters: the maximum impact force, the impact duration, and the rise time. The time when the maximum sound pressure occurred, the influence of the rise time on the sound pressure level, and the vibrational modes which contributed to the sound were obtained using this approximation.

86-1301
Acoustic Scattering by a Rigid Movable Body Immersed in a Fluid
P. Olsson
Institute of Theoretical Physics, Goteborg, Sweden
J. Acoust. Soc. Amer., 78 (6), pp 2132-2114 (Dec 1985) 13 figs, 14 refs

KEY WORDS: Sound waves, Wave scatterings

The problem of scattering of acoustic waves by a rigid movable body immersed in a fluid is solved by means of the null-field approach. The solution is obtained both directly and as a limit of the solution for an elastic body. Numerical results are presented for some rotationally symmetric bodies.

86-1302
A Study of the Sound Reflection from Porous Material by Impulse Method
Zheng Min-hua
AACS, 10 (3), PP 173-179 (1985) CSTA NO. 534-85.17

KEY WORDS: Sound waves, Wave reflection, Porous materials

This paper presents a study of the reflection of sound pulse from porous material in the case that the impulse sound source and receiver are located on a line perpendicular to the surface of material. The transfer functions of reflected sound wave were calculated from the experimental incident and the reflected sound pulses by use of DFT. The impulse response of reflected sound wave can be calculated theoretically under the assumption of idealized porous material. Both local reaction and extended reaction of the material were taken in the calculations. A comparison of the calculations for spherical wave and plane wave provides a measure of the effect of spherical wave on the transfer function of reflected sound wave. For a layer of porous material the reflections in the material are studied.

86-1303
A Novel Method for Solving the Inverse Scattering Problem for Time-Harmonic Acoustic Waves in the Resonance Region
D. Colton, P. Monk
Univ. of Delaware, Newark, DE
SIAM J. Appl. Math., 45 (6), pp 1039-1053 (Dec 1985) 3 figs, 3 tables, 20 refs

KEY WORDS: Sound waves, Wave scattering

The inverse scattering problem we are considering in this paper is to determine the shape of an obstacle from a knowledge of the time-harmonic incident field and the phase and amplitude of the far field pattern of the scattered wave. A method is given which is based on determining the first eigenfunction of the unknown obstacle and which, in addition, avoids the use of integral equations. Numerical examples are given showing that our proposed method is both accurate and simple to use.

86-1304
A Simple Shallow Water Propagation Model Including Shear Wave Effects
D.D. Ellis, D.M.F. Chapman
Defence Research Establishment Atlantic, Dartmouth, Nova Scotia, Canada
J. Acoust. Soc. Amer., 78 (6), pp 2087-2095 (Dec 1985) 9 figs, 1 table, 17 refs

KEY WORDS: Underwater sound, Sound waves, Wave propagation, Normal mode method

The Pekeris model has proved to be very useful in describing some features of acoustic propagation in shallow water, and as a simple test of ideas in normal mode theory. The basic model consists of a homogeneous layer of fluid overlying an infinite homogeneous fluid half-space of greater sound speed. Here, the Pekeris model to handle the case of a fluid overlying an elastic basement in which the shear speed is less than the (compressional) speed of sound in the fluid is extended. This gives rise to leaky modes in which both the mode eigenfunctions and eigenvalues are complex. The model predictions are compared to some measured propagation losses for a shallow water site overlying a chalk bottom, where compressional to shear wave conversion at the water-chalk interface causes large losses. The predictions of the simple model explain the very high losses measured at frequencies less the 200 Hz. At higher frequencies the sound-speed profile, absorption of sound by the water, and the effects of a thin sediment layer become important, but then an all-fluid normal mode model is in agreement with the measured results.

86-1305

Experimental Investigation of Two-Dimensional Diffuse Sound Fields in a Shallow Water Basin

M. Rollwage, K.J. Ebeling, D. Guicking
Universitat Gottingen, Fed. Rep. Germany

Acustica, 58 (3), pp 149-161 (Aug 1985) 19 figs, 22 refs

KEY WORDS: Underwater sound, Statistical analysis

Sound fields in rooms which are excited above Schroeder's large room frequency can suitably be described by statistical methods. In this paper some predictions of the theory of two-dimensional statistical sound fields are verified by measurements in a shallow water basin. The frequency distributions of various sound field quantities are derived from the complex transfer function of the sinusoidally excited water basin. Besides isotropic sound fields, the influence of absorbing walls especially on the distribution of energy flux, spatial variation of phase, and correlation functions are investigated. With larger wavelengths, one approaches the limit of deterministic sound fields where one single eigenmode dominates. The measured frequency distributions agree very well with the theoretical density functions while the spatial correlation functions show the behavior of those in diffuse sound fields only for sufficiently short wavelengths. In particular, in the case of a semidiffuse sound field, the positive influence of Schroeder diffusors is shown by better agreement between measured and theoretical spatial correlation. The degree of diffusion can be inferred from calculated spatial power spectra. Some less usual but very interesting statistical quantities like energy flux, phase variation, or the expectation values for the distances between successive zeros or maxima and the heights of mountains in the spatial sound level distribution are extensively studied experimentally and by computer simulations. The possibility for characterizing sound fields by means of these quantities is discussed.

SHOCK EXCITATION

86-1306

Airblast Attenuation in Entranceways and Other Typical Components of Structures. Small-Scale Tests Data Report 1

J.R. Britt, C.D. Little
Army Engineer Waterways Experiment Station, Vicksburg, MS

Rept. No. WES/TR/SL-84-22, 437 pp (Dec 1984) AD-A157 002/7/GAR

KEY WORDS: Shock wave attenuation, Doors, Blast resistant structures, Experimental data

The objective of this investigation was to develop an experimental data base for the airblast produced by conventional high explosive detonations which intrudes into structures through air entrainment systems, doors, and other openings. This information will provide an experimental basis for the development of airblast prediction methods for the selection of blast doors and blast valves and the design of the geometrical configuration of personnel and air entrainment entranceways to suppress blast. The objective of this report is to present the experimental data obtained in this small-scale explosive test program. The analysis of the measurements will be given in later reports. This report describes the first phase of the experimental effort consisting of a comprehensive small-scale explosive test program conducted in the summer of 1981 and the winter of 1982. The experimental program consisted of a series of spherical charges ranging from 113 to 907 g of composition C-4 explosive detonated outside and inside the entrance of tunnels of circular and square cross-sections.

86-1307

Airblast Attenuation in Entranceways and Other Typical Components of Structures. Small-Scale Tests Data Report 2

C.D. Little
Army Engineer Waterways Experiment Station, Vicksburg, MS

Rept. No. WES/TR/SL-84-23, 287 pp (Dec 1984) AD-A157 003/5/GAR

KEY WORDS: Shock wave attenuation, Doors, Blast resistant structures, Experimental data

Airblast attenuation through entranceways into structural components was investigated in a small-scale explosive test series during 1983. Thirty tests were performed with steel constructed models of square cross section tunnels in configurations typically found in field fortifications and personnel shelters.

86-1308

Failure Analysis of Structures Subjected to Multiple Blast Loads

A. Longinow, J. Mohammadi, E.S. Napadensky
IIT Res. Inst., Chicago, IL

8 pp (Aug 1984) (Minutes of Explosives Safety Seminar (21st) Houston, TX, Aug 28-30, 1984, pp 597-604, Vol. 1) AD-P004 847/0/GAR

KEY WORDS: Blast response, Structural response, Buildings

This paper examines the problem of structural response in a multiple load blast environment. Due to the non-deterministic nature of the problem, the method considers the failure probability of the structure after each blast. The structure is modeled as a single degree of freedom system with a resistance function which provides for an approximation degradation in strength. The method considers uncertainties in both structural and blast load parameters. Load and resistance are assumed to be lognormally distributed. A failure probability is computed after each blast.

86-1309
Design Criteria and Preliminary Acceptance Test Specifications for Blast Resistant Windows
G.E. Meyers
Naval Civil Engrg. Lab., Port Hueneme, CA
62 pp (Aug 1984) (Minutes of Explosives Safety Seminar (21st), Houston, TX, Aug 28-30, 1984, pp 153-214, Vol. 1)

KEY WORDS: Blast resistant structures, Windows, Design techniques

Preliminary design criteria for blast resistant windows exposed to blast overpressures up to 25 psi are recommended. Design procedures and design curves for fully tempered glass are presented and parametized according to glass thickness, glass dimensions, glass aspect ratio, peak blast overpressures, and effective blast duration. Curves for annealed glass are also presented for the purpose of analyzing the safety of existing structures. Design criteria for frames and a test certification procedure are also discussed. Additionally, design examples are presented.

86-1310
Window Panes Loaded by Explosions
A. Harmanny, W. Karthaus, G. Opschoor
Prins Maurits Lab., TNO, Rijswijk, Netherlands
17 pp (Aug 1984) (Minutes of Explosives Safety Seminar (21st), Houston, TX, Aug 28-30, 1984, pp 135-139, Vol. 1) AD-P004 824/9/GAR

KEY WORDS: Blast resistant structures, Windows, Plates

It is possible to calculate the maximum stresses in blast-loaded, rectangular window-panes, with the help of the stresses in the corner of a simply supported plate under pure bending. A value for the strength of glass has been established that may be adjusted for changes in pane area and thickness.

86-1311
Shock Waves in Adjacent Engine Inlets (Stosswellen in Benachbarten Triebwerkseinlaeufen)
G. Patz
Institut Franco-Allemand de Recherches, Saint-Louis, France
Rept. No. ISL-R-104/84, 45 pp (Feb 22, 1984) N85-31068/8/GAR (in German)

KEY WORDS: Shock waves, Wave diffraction, Wave propagation

Shock wave diffraction and propagation in two adjacent inlets is studied to get a general view of the effects on the flow in one open inlet. In a bidimensional test room divided into an inlet closed by a perforated plate and an open inlet, reflection shock waves with variable intensity were generated. The propagation and effects on the flow in the open inlet were studied in Mach numbers ranging from 0.6 to 0.7 to 1.6. Films and streak photographs made with a differential interferometer, and the measured values with a differential laser interferometer show a very weak shock wave in subsonic flow. The shock wave is not observed in supersonic flow. In both cases a perturbation caused by a transverse flow associated with a leading edge vortex separation of the partition wall between the two intakes is observed.

VIBRATION EXCITATION

86-1312
Stationary Response of Combined Linear Dynamic Systems to Stationary Excitation
L.A. Bergman, J.W. Nicholson
Univ. of Illinois, Urbana, IL
J. Sound Vib., 103 (2), pp 225-236 (Nov 22, 1985) 1 fig, 34 refs

KEY WORDS: Random vibrations, Viscous damping, Normal mode method, Modal analysis

The stationary response of a broad class of combined linear systems to stationary random excitation is determined by the normal mode method. The systems are characterized by a viscously damped simple beam (or string, membrane, thin plate of shell, etc.) connected at

discrete points to a multiplicity of viscously damped linear oscillators and/or masses. The solution of the free vibration problem by way of Green functions and the deterministic forced vibration problem by modal analysis for both proportional and non-proportional damping is reviewed. The orthogonality relation for the natural modes of vibration is used to derive a unique relationship between the cross-spectral density functions of the applied forces and the cross-spectral density functions of the generalized forces. Finally, the response spectral density functions and the mean square responses of the beam and oscillators are derived in closed form, exact for the proportionally damped system and approximate for the non-proportionally damped system.

86-1313
Unsteady Forces Acting on a Body Immersed in Viscous Fluids
Takahiko Tanahashi, Tatsuo Sawada, Eriya Kanai, Akira Chino
Keio Univ., Yokohama, Japan
Bull. JSME, 28 (242), pp 1634-1641 (Aug 1985) 10 figs, 15 refs

KEY WORDS: Submerged structures, Viscous medium, Finite difference method

The initial stage of flows due to uniformly accelerated flat plate, elliptic and circular cylinders from rest in incompressible viscous fluids are numerically studied by the finite difference method. The time dependence of stress lines and equi-vorticity lines are shown in flow patterns. The Dufort-Frankel technique is used for solving the vorticity transport equation and the finite Fourier transform for solving the stream function. It is applied to the analysis of a block tridiagonal matrix equation.

86-1314
Force Spectrum of Horizontal Member
C.C. Tung, B. Yin
North Carolina State Univ., Raleigh, NC
ASCE J. Engrg. Mech., 111 (11), pp 1310-1322 (Nov 1985) 4 figs, 6 refs

KEY WORDS: Submerged structures, Wave forces

Expressions of mean value, mean-square value and spectrum are derived for the vertical force on a horizontal member of square cross section partially immersed in water under the actions of normally incident long-crested Gaussian stationary linear wave train. The derivation takes into account the possibilities that the member may at time be totally submerged or out of the water. Numerical results are obtained and presented graphically to show that, depending on whether the probability associated with the events of total submergence and emergence of the members are considered or ignored, the mean value, mean-square value and spectrum of the vertical wave force may be significantly different.

86-1315
Experimental Study on Wave-Induced Structural Responses of Semisubmersibles
T. Yoneya
Nippon Kaiji Kyokai Research Institute, Mitaka, Tokyo, Japan
J. Energy Resources Tech., Trans. ASME, 107 (4), pp 461-466 (Dec 1985) 11 figs, 12 refs

KEY WORDS: Submerged structures, Wave forces

This paper describes experimental studies on the motion, mooring tension and structural responses of a typical semisubmersible in regular waves. A 1/50-scale structural dynamic model of two-pontoon type was made of acryl and tank tests were carefully carried out. The measured platforms motions of the model were compared with calculations and close agreement was obtained. As to the structural responses the measure values of the test model agree approximately with the calculated results of a full-scale model. The close experimental results of structural responses presented here are expected to be valuable for the design of similar types of semisubmersibles.

86-1316
Frequency Characteristics of a Bubble Cluster in a Vibrated Liquid Column
Hiroyuki Hashimoto, Seiichi Sudo
Tohoku Univ., Sendai, Japan
J. Spacecraft Rockets, 22 (6), pp 649-655 (Nov/Dec 1985) 14 figs, 15 refs

KEY WORDS: Fluid-filled containers, Sloshing, Resonant frequencies, Bubble dynamics

The purpose of the present paper is to investigate experimentally the dynamic behavior of the bubble cluster in detail and to clarify the frequency characteristics of the cluster by a theoretical model based on an experimental observation. It is found that the input acceleration required for the inception of the cluster formation is expressed by a semiempirical equa-

tion. By using this equation, it is possible to estimate quantitatively the influences of the ambient pressure and the liquid height of the inception of the cluster. The influence of the geometrical form of the container on the resonant frequency of the cluster is clarified quantitatively. The numerical values obtained by the present theory agree relatively well with the experimental values in both water and glycerol. The frequency characteristics of the liquid sloshing accompanying the cluster are clarified by the present investigation.

86-1317
Dynamic Behavior of Stratified Fluids in a Rectangular Container Subject to Vertical Vibration
Hiroyuki Hashimoto, Seiichi Sudo
Tohoku Univ., Sendai, Japan
Bull. JSME, 28 (243), pp 1910-1917 (Sept 1985) 18 figs, 9 refs

KEY WORDS: Fluid-filled containers, Sloshing

A theoretical and experimental study is presented for the dynamic behavior of two liquid layers with a free surface in a container subject to vertical vibration. This study is concerned with two fluids sloshing phenomena.

86-1318
A Semi-Analytical Method for Structure-Internal Liquid Interaction Problems
Zhiyuan Cao
Appl. Math. Mech., 6 (1), pp 1-8 (1985) CSTA No. 519-85.48

KEY WORDS: Fluid filled containers, Sloshing

A composite structure-internal liquid element is proposed in this paper. Through the use of analytical functions in two orthogonal directions, the three-dimensional problem of coupled structure-internal liquid vibration is reduced to a one-dimensional one, resulting in a drastic reduction in computing efforts. Cylindrical and conical frustum composite elements are proposed to suit different problems, and examples are presented to demonstrate the accuracy of the method.

86-1319
Response of a Compliant Slab to Inviscid Incompressible Fluid Flow
C.A. Evrensel, A. Kalnins
Lehigh Univ., Bethlehem, PA
J. Acoust. Soc. Amer., 78 (6), pp 2034-2041 (Dec 1985) 8 figs, 18 refs

KEY WORDS: Slabs, Fluid-induced excitation

The dynamics of harmonic wave trains on the interface between a compliant slab and the flow of an inviscid fluid is explored theoretically. The slab is treated as an infinite, elastic or viscoelastic solid of finite thickness, bonded to a rigid half-space. The viscoelastic behavior is modeled by an isotropic Voigt constitutive model. The two media are coupled through stress and velocity, normal to the surface of the slab. The proposed mathematical model is used to predict the appearance of unstable surface waves of the coating.

86-1320
Vibrational Analysis in Fluids. 1970-November 1985 (Citations from the Engineering Index Data Base)
NTIS, Springfield, VA
152 pp (Nov 1985) PB85-872273/GAR

KEY WORDS: Vibration response, Fluids, Bibliographies

This bibliography contains citations concerning vibrational fatigue, stress, and mechanical responses of fluids through a range of applications. The report discusses general areas of shapes and mechanisms working within and/or in conjunction with fluids. The general information is experimental in nature and could transfer to numerous fields. Specific data and procedures include applications in mechanical engineering, hydrodynamics, hydraulics, and nuclear reactor technology. This updated bibliography contains 210 citations, 44 of which are new entries to the previous edition.

MECHANICAL PROPERTIES

DAMPING

86-1321
High Temperature Damping of Dynamic Systems
D.I.G. Jones
Materials Lab. (AFWAL/MLLN), Wright-Patterson AFB, OH
Shock Vib. Dig., 17 (10), pp 3-5 (Oct 1985) 28 refs

KEY WORDS: Vibration damping, Thermal damping, Temperature effects, Reviews

This article describes progress in three major areas of high temperature vibration control technology since 1982: high temperature materials, design and applications, and frictional damping.

86-1322
Annular Compressible Squeeze Films
J.J. Blech
Technion -- Israel Institute of Technology, Haifa, Israel
J. Trib., Trans. ASME, 107 (4), pp 544-547 (Oct 1985) 4 figs, 6 refs

KEY WORDS: Squeeze-film dampers, Harmonic excitation

The exact solution for annular isothermal squeeze films in either parallel or tilting simple harmonic motion of small amplitude is derived. Pressure distributions, forces and moments are given for any inner to outer radius ratio. Comparison of cutoff frequencies with approximate values of previous works indicates that for low inner outer radius, there exist deviations between the approximate frequencies to the present values. Damping forces correlate well with Green and Etision's work for low squeeze numbers and moderately large inner to outer radius ratios.

86-1323
Dual Clearance Squeeze Film Damper
D.P. Fleming
NASA Lewis Res. Ctr., Cleveland, OH
U.S. PATENT-4 527 910, 8 pp (July 9, 1985)

KEY WORDS: Squeeze-film dampers

A dual clearance hydrodynamic liquid squeeze film damper for a gas turbine engine is described. Under normal operating conditions, the device functions as a conventional squeeze film damper, using only one of its oil films. When an unbalance reaches abusive levels, as may occur with a blade loss or foreign object damage, a second, larger clearance film becomes active, controlling vibration amplitudes in a near optimum manner until the engine can be safely shut down and repaired.

FATIGUE

86-1324
Retardation of Fatigue Crack Propagation Due to Additional Holes or Identations in Plate Specimens
Hiroomi Miyagawa, Hironobu Nisitani
Oita Univ., Oita, Japan
Bull. JSME, 28 (244), pp 2219-2223 (Oct 1985) 10 figs, 2 refs

KEY WORDS: Fatigue life, Crack propagation, Plates, Hole-containing media, Discontinuity-containing media

This paper is concerned with the beneficial effects of additional holes or indentations on fatigue crack propagation. Two indentations facing each other at the tip of a crack are effective for retardation of crack propagation. The effect of the indentations can be approximately estimated from the existence of residual stresses produced by the indentations.

EXPERIMENTATION

MEASUREMENT AND ANALYSIS

86-1325
New Method for Compensating and Measuring Any Motion of Three-Dimensional Objects in Holographic Interferometry
A. Stimpfling, P. Smigielski
Institut Franco-Allemand de Recherches, Saint Louis, France
Rept. No. ISL-CO-216/84, 14 pp (July 12, 1985) (4th Journees Professionelles Opto-Electron, Opto 84, Paris, Mar 15-17, 1984) N85-33474/6/GAR (in French, English summary)

KEY WORDS: Amplitude measurement, Holographic techniques, Interferometric techniques

A method to correct a general displacement (three translations and three rotations) is presented. Tests were done by real time and by double exposure holographic interferometry. The diffuse test object was subject to in-plane translations of 5 mm, out of plane tranalation of 1 mm, and rotations. With these amplitudes no interference fringes are visible but compensation is possible. Interference fringes progressively appear and finally the infinite fringe is obtained.

The method used with a computer should allow the measurement of the different components of the motion even if its amplitude is greater than the dimensions of the object.

86-1326
Adaptive Identification and Control of Structural Dynamics Systems Using Recursive Lattice Filters
N. Sundarajan, R.C. Montgomery, J.P. Williams
NASA Langley Res. Ctr., Hampton, VA
Rept. No. L-15737, NASA-TP-2371, 51 pp (Jan 1985) N85-31142/1/GAR

KEY WORDS: System identification techniques, Least squares method, Vibration control, Modal control techniques

A new approach for adaptive identification and control of structural dynamic systems by using least squares lattice filters that are widely used in the signal processing area is presented. Testing procedures for interfacing the lattice filter identification methods and modal control method for stable closed loop adaptive control are presented. The methods are illustrated for a free-free beam and for a complex flexible grid, with the basic control objective being vibration suppression.

86-1327
Modal Parameter Extraction Procedure Applicable to Linear Time-Invariant Dynamic Systems
A.J. Kurdila, R.R. Craig
TexasUniv., Austin, TX
Rept. No. CAR-85-2, NASA-CR-176120, 97 pp (May 1985) N85-33747/5/GAR

KEY WORDS: Modal analysis, Linear systems, Parameter identification technique

A new modal parameter estimation procedure is presented. The technique is applicable to linear, time-invariant systems and accommodates multiple input excitations. In order to provide a background for the derivation of the method, some modal parameter extraction procedures currently in use are described. Key features implements in the new technique are elaborated.

86-1328
Modal Synthesis Via Combined Experimental and Finite Element Techniques with Consideration of Rotational Effects
W.-H. Chen, J.-S. Cherng
National Tsing Hua University, Hsinchu, Taiwan, Rep. of China
J. Sound Vib., 103 (1), pp 1-11 (Nov 8, 1985) 9 figs, 25 refs

KEY WORDS: Modal synthesis, Constraint modes method, Finite element technique, Rotatory inertia effects

This paper presents a simple and effective modal synthesis method via combined experimental and finite element techniques in which the "constraint modes method" is used to determine the dynamic properties of complex structures. To satisfy the rotational compatibility at the common boundary, an experimental procedure is proposed to measure the generalized dynamic compliance. To demonstrate the versatility and applicability of the techniques developed, two simple systems of beam-beam and plate-beam type structures are investigated. Excellent agreement is shown between the synthesized results and reference solutions obtained from analysis of the entire structure by using only the finite element technique.

86-1329
Dynamic Analysis of Multibody Systems Using Component Modes
O.P. Agrawal, A.A. Shabana
Univ. of Illinois at Chicago, Chicago, IL
Computers Struc., 21 (6), pp 1303-1312 (1985) 8 figs, 15 refs

KEY WORDS: Component mode analysis, Multibody systems

This paper is concerned with dynamic analysis of flexible multibody systems. The configuration of each elastic components is identified by three sets of modes; rigid-body, reference, and normal modes. Rigid body modes are introduced using a set of Lagrangian coordinates that describe rigid-body translation and large rotations of a body reference. Reference modes are defined using a set of reference conditions that are required to define a unique displacement field. These reference conditions, that define the nature of the body axes, have to be consistent with the system constraint equations. Their number should be equal or greater than the number of the rigid-body modes. Normal modes, however, define the deformation relative to the body reference. An automated scheme for imposing the boundary conditions of a constrained flexible component in a multibody system is presented. It is also shown that the mean axis and the body-fixed axis are the result of imposing a special set of reference conditions.

86-1330
A General Purpose, Multi-Stage, Component Modal Synthesis Method
D.N. Herting
The MacNeal-Schwendler Corporation, Los Angeles, CA
Finite Elements Analy. Des., 1 (2), pp 153-164 (Aug 1985) 1 fig, 1 table, 15 refs

KEY WORDS: Component mode synthesis, Finite element technique

A general purpose algorithm for the dynamic analysis of large-order finite element structural models using real modal coordinates is presented. Each component substructure may be formulated to include free or fixed boundary modes, inertia relief displacement shapes, and physical displacement as generalized degrees of freedom. Capabilities are developed for transforming interior loads, such as aerodynamic effects, to the reduced set of coordinates. Theory and tests prove that the method duplicates results from most of the other popular methods by selecting various optional terms. The conclusion contains practical recommendations based upon several applications to structural analysis.

86-1331
Multishaker Modal Testing
R.R. Craig
Texas Univ., Austin, TX
Rept. No. CAR-85-3, NASA-CR-176139, 17 pp (May 1985) N85-33544/6/GAR

KEY WORDS: Component mode synthesis, Experimental modal analysis, Multiple shakers, Damped structures

A component mode synthesis method for damped structures was developed and modal test methods were explored which could be employed to determine the relevant parameters required by the component mode synthesis method. Research was conducted on the time-domain component mode synthesis technique for damped systems; a frequency-domain component mode synthesis method for damped systems; a system identification algorithm applicable to general damped systems. Abstracts are presented of the major publications which have been previously issued on these topics.

86-1332
Substructure Coupling Procedure Applicable to General Linear Time-Invariant Dynamic Systems
T.G. Howsman, R.R. Craig
Texas Univ., Austin, TX
Rept. No. CAR-84-1, NASA-CR-176144, 88 pp (May 1984) N85-33542/0/GAR

KEY WORDS: Substructuring methods, Ritz vectors

A substructure synthesis procedure applicable to structural systems containing general nonconservative terms is presented. An example problem is presented to illustrate the method.

86-1333
Substructure Coupling in the Frequency Domain
Texas Univ., Austin, TX
Rept. No. CAR-85-1, NASA-CR-176140, 128 pp (May 1985) N85-33543/8/GAR

KEY WORDS: Substructuring methods, Frequency domain method

Frequency domain analysis was found to be a suitable method for determining the transient response of systems subjected to a wide variety of loads. However, since a large number of calculations are performed within the discrete frequency loop, the method loses its computation efficiency if the loads must be represented by a large number of discrete frequencies. It was also discovered that substructure coupling in the frequency domain work particularly well for analyzing structural system with a small number of interface and loaded degrees of freedom. It was discovered that substructure coupling in the frequency domain can lead to an efficient method of obtaining natural frequencies of undamped structures. It was also found that the damped natural frequencies of a system may be determined using frequency domain techniques.

86-1334
Observability of Analytically Predicted Modal Behaviour
J.A. Brandon
University of Wales, Cardiff, Wales
Rept. No. UWIST-DMEEP/DAG-146, 7 pp (1984) PB85-228708/GAR

KEY WORDS: Experimental modal analysis

A common problem in experimental modal analysis is that it is not possible to observe experimentally a mode which has been predicted by a theoretical analysis. This often occurs where a number of modes have closely spaced natural frequencies. In this cast it may also happen

that due to discrepancies between model and experimental results it is not even possible to say which mode(s) are missing. In this discussion a possible explanation of this phenomenon will be offered with suggestions on how to resolve the missing modes experimentally.

86-1335
System Identification for Determination of Dynamic Properties from Forced-Vibration Testing
A.N. Lin
Kansas State Univ., Manhatten, KS
Exptl. Tech., 9 (11), pp 22-28 (Nov 1985) 7 figs, 11 refs

KEY WORDS: Experimental modal analysis, Least squares method, Resonant frequencies, Damping coefficients, System identification techniques

This article presents a method based on a least-squares fit of determining the resonant frequency and modal-damping values from the results of forced-vibration testing using techniques that have been developed for systems identification.

86-1336
Multiple-Input Excitation Using Burst Random for Modal Testing
R. Zimmerman, D.L. Hunt
QUIXOTE Measurement Dynamics, Inc., Cincinnati, OH
S/V Sound Vib., 19 (10), pp 12-21 (Oct 1985) 7 figs, 12 refs

KEY WORDS: Experimental modal analysis, Aircraft, Multipoint excitation technique, Burst random technique

Two recent developments in modal testing of aircraft by the frequency response method are the application of multiple exciters and the use of the burst random (or random transient) excitation signals. Developed separately, each has been proven useful when implemented alone. This article reviews the characteristics of each, and presents the advantages of using them together. It also shows some results for the ground vibration testing and modal analysis of three airplanes, demonstrating these advantages.

DYNAMIC TESTS

86-1337
Personal Computers in Environmental Test Laboratories
D.B. Page
Hughes Aircraft Co., Los Angeles, CA
S/V Sound Vib., 19 (11), pp 20-23 (Nov 1985) 1 table, 6 refs

KEY WORDS: Test facilities, Computer-aided techniques

Personal computers (PCs) are appearing in more and more applications supporting environmental test laboratories. Connected to data loggers, controllers, voice synthesizers, spectrum analyzers, and other instruments, PCs analyze data, monitor alarm limits, and control tests. This article puts the application of PCs to environmental test labs in perspective. Results from a small survey of PC users are annotated by the author's experiences.

86-1338
Digital Data Acquisition System for Modal Testing
R.D. Talmadge, D.L. Banaszak
Air Force Wright Aeronautical Lab., Wright-Patterson AFB, OH
S/V Sound Vib., 19 (11), pp 12-16 (Nov 1985) 5 figs, 1 table, 4 refs

KEY WORDS: Test facilities, Experimental modal analysis, Data recorders, Aircraft

The Structural Vibration and Acoustics Branch (FIBG) of the Air Force Wright Aeronautical Laboratories (AFWAL) conducted a ground vibration test (GVT) on a full scale F-16 aircraft located inside FIBG's vibra-acoustic facility at Wright-Patterson AFB, OH. A complete data acquisition system to measure and condition up to 120 transducer signals was designed and fabricated to support the GVT. This article describes the design, evaluation, calibration and use of the test instrumentation system.

86-1339
Ultrasonics in Nondestructive Evaluation
R.B. Thompson, D.O. Thompson
Iowa State Univ., Ames, IA
IEEE, Proc., 73 (12), pp 1716-1755 (Dec 1985) 45 figs, 340 refs

KEY WORDS: Nondestructive tests, Ultrasonic techniques

The use of ultrasonic waves in nondestructive evaluation is reviewed. Perspective is provided by a summary of the role played by nondestructive evaluation in the manufacture and utilization of structural components. Included are discussions of the methodologies for predicting part serviceability and of the constraints placed on the nondestructive measurement process by the mechanical designs and functions of structural components. The principles of active (ultrasonic) and passive (acoustic-emission) testing techniques are then reviewed. Specific examples of applications from several industries illustrate the capabilities and limitations of state-of-the-art techniques based on these principles. Detailed discussion is then given of present research and development activities designed to overcome these limitations, with particular emphasis on those areas best addressed by the tools of electrical engineering. Included are discussions of instrumentation, inspection performance modeling, flaw sizing techniques (including imaging systems), material property measurement techniques, and acoustic-emission techniques. The paper concludes with a consideration of important directions of future work.

86-1340
Tape Joint Design for a Vibration Table
R.P. Rechard, R.L. Mayes
Sandia National Labs., Albuquerque, NM
Rept. No. SAND-84-1159, 51 pp (July 1984) DE85012617/GAR

KEY WORDS: Shakers, Joints, Test facilities

The connection of a vibration shaker to its companion horizontal slip table with a large tape joint is proposed. An improved connection is needed to reduce the tie taken to switch the shaker from the vertical to the horizontal position and to transmit greater vibration to components bolted to the slip table. The distinct advantages of the tape joint - self alignment, low mass, and joint stiffness - are important for the connection. For this tape joint design, the joint upset was eliminated; thus the standard design procedure was modified somewhat.

86-1341
Acoustic-Emission Monitoring of Composite Damage Occurring Under Static and Impact Loading
D.S. Gardiner, L.H. Pearson
Hercules Aerospace Division, Magna, UT
Exptl. Tech., 9 (11), pp 22-28 (Nov 1985) 10 figs, 6 refs

KEY WORDS: Acoustic emission, Testing techniques, Fracture properties

In the present investigation, two acoustic-emission techniques were evaluated to determine if additional information about the nature of the fracture processes that occur during the impact event could be obtained. Tests were conducted on flat graphite/epoxy plates of one-laminate configuration.

DIAGNOSTICS

86-1342
Interpreting Vibration Information from Rotating Machinery
D.E. Bentley, S. Zimmer, G.E. Palmatier, A. Muszynska
Bently Nevada Corp., Minden, NV
S/V Sound and Vibration, 20
1986) 26 figs, 2 tables, 18 refs

KEY WORDS: Diagnostic instrumentation, Diagnostic techniques, Rotating machinery

As instrumentation and computer information processing technologies continue to advance, concern is shifting from how to obtain rotating machinery vibration information to methods for interpreting the information. This article discussed information requirements and display formats for using vibration information in machine analysis and predictive maintenance programs. It also presents examples of machinery malfunctions that illustrate how these information display techniques can be utilized.

86-1343
Evaluation of a Prototype Acoustic Signature Inspection System for Railroad Wheels
S. Haran, S.M. Rocha, R.D. Finch
Acoustic Systems, Inc., Houston, TX
Rept. No. RS-1, DOT/FRA/ORD-84/19, 162 pp (May 1985) PB85-225183/GAR

KEY WORDS: Diagnostic instrumentation, Acoustic signatures, Railway wheels

A description is given of considerations in the design of a prototype acoustic signature inspec-

tion system for railroad wheels. The evolution of each of the components of the system is detailed including hammers, microphones, wheel sensors, wayside electronics and signal conditions unit. The structure of the software is described. Data acquisition procedures, the data base and evaluation of the wheel classification algorithms are also described.

MONITORING

86-1344
Applications of Vibration Analysis to the Condition Monitoring of Rolling Element Bearings
N.S. Swansson, S.C. Favaloro
Aeronautical Res. Labs., Melbourne, Australia
Rept. No. ARL/AERO-PROP-R-163, 105 pp (Jan 1984) AD-A157 210/6/GAR

KEY WORDS: Monitoring techniques, Rolling contact bearings

Condition monitoring methods for rolling element bearings which utilize the high frequency vibrations generated by bearing damage, have been investigated and compared experimentally. Kurtosis values, spectra of vibration signal enveloped, and pulse measurement methods provided effective detection of early damage. Kurtosis in particular was not effective in evaluating extensive damage, where a combination of methods is required. Comparison of different accelerometer types used as vibration sensors gave very similar results. An acoustic emission transducer provided indications of incipient damage significantly earlier than the accelerometers. Tests were conducted under reasonably favorable conditions of measurement so further testing under less favorable conditions is proposed, and the effect of such conditions is briefly considered.

ANALYSIS AND DESIGN

ANALYTICAL METHODS

86-1345
A Stochastic Model for Nonlinear Oscillators of Duffing Type
R. Spigler
New York Univ., New York, NY
SIAM J. Appl. Math., 45 (6), pp 990-1005 (Dec 1985) 3 figs, 14 refs

KEY WORDS: Nonlinear theories, Stochastic processes, Duffing oscillators

A nonlinear model for random oscillators, which includes a stochastic version of the Duffing oscillator in both cases of hard and soft spring, is studied in the diffusion limit. This is an asymptotic limit involving random fluctuations of small size, and long time. The nonlinearity is also assumed to be small. One of the main results is that the effect of the type and size of nonlinearity under investigation does not affect appreciably the qualitative long-time behavior of the moments of the displacement of the oscillator, in both the hard and the soft spring models. It is also proved that there are no stationary distributions. Finally, a numerical study for the first two moments is performed and plots are given.

86-1346
The Response of One-Degree-of-Freedom Systems with Cubic and Quartic Non-linearities to a Harmonic Excitation
A.M. Abu-Arish, A.H. Nayfeh
Virginia Polytechnic Institute and State Univ., Blacksburg, VA
J. Sound Vib., 103 (2), pp 253-272 (Nov 22, 1985) 14 figs, 6 refs

KEY WORDS: Harmonic excitation, Single degree of freedom systems, Multiple scale method

The method of multiple scales is used to analyze the response of single-degree-of-freedom systems with cubic and quartic nonlinearities to a harmonic excitation. Two first-order ordinary differential equations describing the evolution of the amplitude and the phase are derived for superharmonic resonances of order two and four, subharmonic resonances of order one-half and one-fourth, and the supersubharmonic resonances of order 3/2 and 2/3. In all cases, the steady state solutions and their stability are determined and representative numerical results are included.

86-1347
Perturbation Analysis of Forced Nonlinear Oscillations Using Symbolic and Numerical Computations
G.C. Atallah
Ph.D. Thesis, State Univ. of New York at Binghamton, 201 pp (1985) DA8514635

KEY WORDS: Perturbation theory, Harmonic excitation

The perturbation method of multiple time scales and the symbolic manipulation system MACSYMA are used as primary tools to analyze the response for some problems in nonlinear oscillations under the action of multiple harmonic excitations. The behavior of a forced Van der Pol Oscillator for three different cases is reported.

86-1348
Transformation Method for the Evaluation of the Response Moments of Elastic Structures with Random Properties
R.H. Bennett
Air Force Inst. of Technology, Wright-Patterson AFB, OH
Rept. No. AFIT/CI/NR-85-46D, 169 pp (Apr 1985) AD-A156 882/3/GAR

KEY WORDS: Elastic systems, Random parameters, Stiffness coefficients, Damping coefficients, Transformation techniques

In this investigation a new method for computing the first and second moments of the displacement response of linear elastic structures with random stiffness and damping is developed. The method accurately computes the mean and variance of the displacement of a dynamically loaded structure as functions of time. The probability that the displacement will be greater than a specified value is also computed. The results of the transformation method are compared to exact solutions for a number of classes. The influence of the randomness in the underlying parameters on the randomness of the response is discussed.

86-1349
A General Method for the Dynamic Response Analysis of Fluid-Structure Systems
S.K. Sharan, G.M.L. Gladwell
Laurentian Univ., Sudbury, Canada
Computers Struc., 21 (5), pp 937-943 (1985) 4 figs, 3 tables, 23 refs

KEY WORDS: Fluid-structure interaction, Finite element technique

A general method is proposed for the dynamic response analysis of fluid-structure systems. The method is based on the finite element discretization of the complete system assuming pressure to be the nodal unknown for the compressible fluid domain. All the matrices involved in the computation are made to be symmetrical and banded. Some approximations are suggested which result in great computational advantages with no significant loss of accuracy. The major computational efforts required for the analysis of the complete system is reduced to that for the independent analyses of the two subsystems. The effectiveness of the proposed method is demonstrated by solving some example problems.

86-1350
Direct Method for Computation of Frequencies in Structures with Constrained Displacements
P. Rubio
Dragados y Construcciones, S.A., Madrid, Spain
Computers Struc., 21 (5), pp 1035-1046 (1985) 15 refs

KEY WORDS: Natural frequencies, Constrained structures

An alternative to the master-slave algorithm to reduce the number of degrees of freedom of structural systems conditioned by linear homogeneous constraints is presented. The theoretical basis of the method includes a penalty term in the definition of the variational principle and the consideration of its asymptotic behavior. The method is analyzed for singular and nonsingular mass matrices and applied to some actual cases encountered in structural practice.

86-1351
Control of Elastic Plane Wave Dispersion in Two-Dimensional Finite Element Meshes
K.D. Ta, R.J. Rogers
Univ. of New Brunswick, Fredericton, NB
Computers Struc., 21 (6), pp 1145-1151 (1985) 8 figs, 1 table, 20 refs

KEY WORDS: Elastic waves, Wave propagation, Finite element technique

The control of discretization dispersion and spurious oscillations in finite element plane wave propagation problems is examined. Using a lumped mass spatial discretization and an explicit temporal integration, two-dimensional plane strain and plane stress meshes are considered. The control of the discretization errors in uniform meshes is very effective using a time step exactly equal to the stability limit. The magnitudes of spurious wave reflections in non-uniform meshes depend largely on the ratio of element lengths. Actual stress wave transmissions and reflections in composite bars are accurately predicted.

MODELING TECHNIQUES

86-1352
Wave-Theoretical Approach to Seismic Modeling Problems (Welmod)
J. Satdleger, G. Dohr
Settlegger Ingenieurbuero fuer Angewandte Geophysik, Meppen, Fed. Rep. Germany
Rept. No. BMFT-FB-T-84-258, 99 pp (Dec 1984) N85-29429/6/GAR (in German)

KEY WORDS: Seismic waves, Finite difference technique, Mathematical models

The propagation of seismic compressional waves in two-dimensional arbitrarily heterogeneous media was investigated. Seismic model experiments were performed and a finite difference modeling program based on the elastic wave equation was developed. An inverse modeling system for seismic reflection data based on the scalar wave equation is developed.

NONLINEAR ANALYSIS

86-1353
A New Method of Dynamic Analysis for Linear and Nonlinear Systems
E.L. Wilson
Univ. of California, Berkeley, CA
Finite Elements Analy. Des., 1 (1), pp 21-23 (Apr 1985) 1 fig, 2 tables, 5 refs

KEY WORDS: Ritz vectors, Nonlinear systems

A new method of dynamic analysis is proposed which involves the superposition of vectors which are not exact eigenvectors. The efficiency and accuracy of the approach has been demonstrated for linear systems. The purpose of this paper is to summarize the method and to indicate that the technique can be extended to multilevel substructures and to structural systems with a limited number of nonlinear members.

STATISTICAL METHODS

86-1354
Prediction of Total Loss Factors of Structures, I: Theory and Experiments
J.C. Sun, E.J. Richards
Univ. of Southampton, Southampton, England
J. Sound Vib., 103 (1), pp 109-117 (Nov 8, 1985) 4 figs, 13 refs

KEY WORDS: Loss factor, Statistical energy methods

A method for calculating the total loss factors of a complex structure has been derived by using Statistical Energy Analysis (SEA). The derived formulae have been simplified on the assumption that coupling between substructures except for the measured substructure is very weak. In two limiting situations, "damping addition" formulae have been obtained. The formula has been applied to predict the total loss factors of a steel box and these results are compared with actual experimental measurements. The agreement between estimated and measured values was in most cases quite good.

DESIGN TECHNIQUES

86-1355
Assessment of Structural Dynamic Reanalysis Techniques Which Use Only Experimental Data
J. Brandon
Univ. of Wales, Cardiff, Wales
Rept. No. UWIST-DMEEP/DAG-151, 25 pp (1984) PB85-228724/GAR

KEY WORDS: Structural modification techniques

Analytical methods which use experimental data to predict the effects of design changes have a wide range of applications. For the procedures discussed here it is unnecessary to synthesize an accurate representation of the properties of the structure. Because the predictions are based on a relatively small amount of information the power of the methods is limited. The necessary conditions for the validity of the strategies are presented here. The methods are particularly suitable for "troubleshooting" applications, where a full structural model is often logistically impossible or economically prohibitive to derive.

COMPUTER PROGRAMS

86-1356
Large Scale Structural Synthesis
G.N. Vanderplaats, H. Miura, M. Chargin
Univ. of California, Santa Barbara, CA
Finite Elements Analy. Des., 1 (2), pp 117-128 (Aug 1985) 8 figs, 3 tables, 9 refs

KEY WORDS: Structural synthesis, Computer programs, Finite element technique, Optimization

A general purpose optimization program is coupled to a large scale finite element program to provide an efficient tool for structural synthesis. The resulting interface program may be used to design structures for minimum weight, subject to constraints on stress, displacement, and vibration frequencies. A variety of state-of-the-art techniques are employed, including design variable linking, constraint deletion, reciprocal variables, and formal approximations. The capability is demonstrated with a design of a gear housing using 30 design variables and over 5000 nonlinear inequality constraints. The finite element model consists of over 1600 elements and 7000 displacement degrees of freedom. The design required six detailed finite element analyses and approximately one hour on a Cray-1s supercomputer. It is concluded that structures of practical size and complexity can be efficiently designed using numerical optimization.

86-1357
DYSCO: An Executive Control System for Dynamic Analysis of Synthesized Structures
P.W. Hurst, A. Berman
Kaman Aerospace Corp., Bloomfield, CT
Vertica, 9 (4), pp 307-316 (1985) 5 figs, 2 tables, 11 refs

KEY WORDS: Computer programs, Aerodynamic loads

The Dynamic Coupling Program (DYSCO) is a fully-interactive Executive Control System for modeling dynamic and aerodynamic phenomena. The system is composed of an Executive Complex which provides user-oriented modeling commands, a Data Base Management Complex and a Technology Complex which provides an expandable library of technological component, force, and solution algorithms. The three software complexes are designed and integrated to specifically support a basic modeling scenario which provides for user-defined coupled model definition, automatic dynamic coupling to formulate the system equations and execution of user-selected solution algorithms. With the capability to treat a broad spectrum of simple and complex problems and with well-defined interfaces and procedures for installation of new technology DYSCO can be used as a repository for current and future dynamic analysis methodologies and as a test bed for the evaluation of new physical and mathematical representations.

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Off-shore Structures

VEHICLE SYSTEMS

Ground Vehicles
Ships
Aircraft
Missiles and Spacecraft

BIOLOGICAL SYSTEMS

Human
Animal

MECHANICAL COMPONENTS

Absorbers and Isolators
Springs
Tires and Wheels
Blades
Bearings
Belts
Gears
Clutches
Couplings
Fasteners
Linkages
Valves
Seals
Cams

STRUCTURAL COMPONENTS

Strings and Ropes
Cables
Bars and Rods
Beams
Cylinders
Columns
Frames and Arches
Membranes, Films, and Webs
Panels
Plates
Shells
Rings
Pipes and Tubes
Ducts
Building Components

ELECTRIC COMPONENTS

Controls (Switches, Circuit Breakers
Motors
Generators
Transformers
Relays
Electronic Components

DYNAMIC ENVIRONMENT

Acoustic Excitation
Shock Excitation
Vibration Excitation
Thermal Excitation

MECHANICAL PROPERTIES

Damping
Fatigue
Elasticity and Plasticity
Wave Propagation

EXPERIMENTATION

Measurement and Analysis
Dynamic Tests
Scaling and Modeling
Diagnostics
Balancing
Monitoring

ANALYSIS AND DESIGN

Analogs and Analog Computation
Analytical Methods
Modeling Techniques
Nonlinear Analysis
Numerical Methods
Statistical Methods
Parameter Identification
Mobility/Impedance Methods
Optimization Techniques
Design Techniques
Computer Programs

GENERAL TOPICS

Conference Proceedings
Tutorials and Reviews
Criteria, Standards, and Specifications
Bibliographies
Useful Applications

CALENDAR

JUNE

3-6 Symposium and Exhibit on Noise Control [Hungarian Optical, Acoustical, and Cinematographic Society; National Environmental Protection Authority of Hungary] Szeged, Hungary (Mrs. Ildiko Baba, OPAKFI, Anker koz 1, 1061 Budapest, Hungary)

8-12 Symposium on Dynamic Behavior of Composite Materials, Components and Structures [Society for Experimental Mechanics] New Orleans, LA (R.F. Gibson, Mech. Engrg. Dept., University of Idaho, Moscow, ID 83843 - (208) 885-7432)

24-26 Machinery Vibration Monitoring and Analysis Meeting [Vibration Institute] Las Vegas, NV (Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 W. 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254)

JULY

14-16 Intersociety Environments Systems [SAE], San Diego, CA (412-776-4841)

20-24 Pressure Vessels and Piping Conference and Exhibition [ASME, concurrent with International Computers in Engineering Conference and Exhibit], Chicago, IL (212-705-7057)

20-24 International Computers in Engineering Conference and Exhibition [ASME] Chicago, IL (ASME)

21-23 INTER-NOISE 86 [Institute of Noise Control Engineering] Cambridge, MA (Professor Richard H. Lyon, Chairman, INTER-NOISE 86, INTER-NOISE 86 Secretariat, MIT Special Events Office, Room 7-111, Cambridge, MA 02139)

24-31 12th International Congress on Acoustics, Toronto, Canada (12th ICA Secretariat, P.O. Box 123, Station Q, Toronto, Ontario, Canada M4T 2L7)

SEPTEMBER

14-17 International Conference on Rotordynamics [IFToMM and Japan Society of Mechanical Engineers] Tokyo, Japan (Japan Society of Mechanical Engineers, Sanshin Hokusei Bldg., 4-9, Yoyogi 2-chome, Shibuyak-ku, Tokyo, Japan)

16-18 Fall National Design Engineering Conference and Show (Cahners Exposition Group, New York, NY 203-964-0000)

21-23 Petroleum Workshop and Conference, Calgary, Canada (214-358-7601)

22-25 World Congress on Computational Mechanics [International Association of Computational Mechanics] Austin, Texas (WCCM/TICOM, The University of Texas at Austin, Austin, TX 78712)

29-30 VDI Vibrations Meeting [Society of German Engineers] Wurzburg, Fed. Rep. Germany (Society of German Engineers)

30-3 6th International Conference on Nondestructive Testing, Strasbourg, France (M.P. Pomes, 25 rue de Chong, 26500 Bourg les Valence, France)

OCTOBER

5-8 Design Automation Conference [ASME] Columbus, OH (ASME)

5-8 Mechanisms Conference [ASME] Columbus, OH (ASME)

7-9 2nd International Symposium on Shipboard Acoustics ISSA '86 [Institute of Applied Physics TNO] The Hague, The Netherlands (J. Buiten, Institute of Applied Physics TNO, P.O. Box 155, 2600 AD Delft, The Netherlands, Telephone: xx31 15787053, Telex: 38091 tpddt nl)

14-16 57th Shock and Vibration Symposium [Shock and Vibration Information Center] New Orleans, LA (Dr. J. Gordan Showalter, Acting Director, *SVIC, Naval Research Lab., Code* 5804, Washington, D.C. 20375-5000 - (202) 767-2220)

19-23 Power Generation Conference [ASME] Portland, OR (ASME)

20-22 Lubrication Conference [ASME] Pittsburgh, PA (ASME)

NOVEMBER

3-6 14th Space Simulation Conference [IES, AIAA, ASTM, NASA] Baltimore, MD (Institute of Environmental Sciences, 940 E. Northwest Highway, Mt. Prospect, IL 60056 - (312) 255-1561)

7-14 Turbomachinery Symposium, Corpus Christi, TX (Turbomachinery Laboratories, Dept. of Mech. Engrg., Texas A & M Univ., College Station, TX 77843)

30-5 American Society of Mechanical Engineers, Winter Annual Meeting [ASME] San Francisco, CA (ASME)

DECEMBER

7-12 ASME Winter Annual Meeting, Anaheim, CA (ASME, United Engrg. Center, 345 East 45th Street, New York, NY 10017)

8-12 ASA, Anaheim, CA (Joie P. Jones, Dept. Radiology Sciences, Univ. of California, Irvine, CA 92717)

CALENDAR ACRONYM DEFINITIONS AND ADDRESSES OF SOCIETY HEADQUARTERS

AHS American Helicopter Society
1325 18 St. N.W.
Washington, D.C. 20036

AIAA American Institute of Aeronautics and Astronautics
1633 Broadway
New York, NY 10019

ASA Acoustical Society of America
335 E. 45th St.
New York, NY 10017

ASCE American Society of Civil Engineers
United Engineering Center
345 E. 47th St.
New York, NY 10017

ASLE American Society of Lubrication Engineers
838 Busse Highway
Park Ridge, IL 60068

ASME American Society of Mechanical Engineers
United Engineering Center
345 E. 47th St.
New York, NY 10017

ASTM American Society for Testing and Materials
1916 Race St.
Philadelphia, PA 19103

ICF International Congress on Fracture
Tohoku University
Sendai, Japan

IEEE Institute of Electrical and Electronics Engineers
United Engineering Center
345 E. 47th St.
New York, NY 10017

IES Institute of Environmental Sciences
940 E. Northwest Highway
Mt. Prospect, IL 60056

IMechE Institution of Mechanical Engineers
1 Birdcage Walk, Westminster
London SW1, UK

IFToMM International Federation for Theory of Machines and Mechanisms
U.S. Council for TMM
c/o Univ. Mass., Dept. ME
Amherst, MA 01002

INCE Institute of Noise Control Engineering
P.O. Box 3206, Arlington Branch
Poughkeepsie, NY 12603

ISA Instrument Society of America
67 Alexander Dr.
Research Triangle Pk., NC 27709

SAE Society of Automotive Engineers
400 Commonwealth Dr.
Warrendale, PA 15096

SEE Society of Environmental Engineers
Owles Hall, Buntingford, Hertz.
SG9 9PL, England

SESA Society for Experimental Mechanics (formerly Society for Experimental Stress Analysis)
14 Fairfield Dr.
Brookfield Center, CT 06805

SNAME Society of Naval Architects and Marine Engineers
74 Trinity Pl.
New York, NY 10006

SPE Society of Petroleum Engineers
6200 N. Central Expressway
Dallas, TX 75206

SVIC Shock and Vibration Information Center
Naval Research Laboratory
Code 5804
Washington, D.C. 20375-5000

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PUBLICATION POLICY

Unsolicited articles are accepted for publication in the **Shock and Vibration Digest.** Feature articles should be tutorials and/or reviews of areas of interest to shock and vibration engineers. Literature review articles should provide a subjective critique/summary of papers, patents, proceedings, and reports of a pertinent topic in the shock and vibration field. A literature review should stress important recent technology. Only pertinent literature should be cited. Illustrations are encouraged. Detailed mathematical derivations are discouraged; rather, simple formulas representing results should be used. When complex formulas cannot be avoided, a functional form should be used so that readers will understand the interaction between parameters and variables.

Manuscripts must be typed (double-spaced) and figures attached. It is strongly recommended that line figures be rendered in ink or heavy pencil and neatly labeled. Photographs must be unscreened glossy black and white prints. The format for references shown in **Digest** articles is to be followed.

Manuscripts must begin with a brief abstract, or summary. Only material referred to in the text should be included in the list of References at the end of the article. References should be cited in text by consecutive numbers in brackets, as in the following example:

> Unfortunately, such information is often unreliable, particularly statistical data pertinent to a reliability assessment, as has been previously noted [1].
>
> Critical and certain related excitations were first applied to the problem of assessing system reliability almost a decade ago [2]. Since then, the variations that have been developed and practical applications that have been explored [3-7] indicate . . .

The format and style for the list of References at the end of the article are as follows:

- -- each citation number as it appears in text (not in alphabetical order)
- -- last name of author/editor followed by initials or first name
- -- titles of articles within quotations, titles of books underlined
- -- abbreviated title of journal in which article was published (see Periodicals Scanned list in January, June, and December issues)
- -- volume, issue number, and pages for journals; publisher for books
- -- year of publication in parentheses

A sample reference list is given below.

1. Platzer, M.F., "Transonic Blade Flutter -- A Survey," Shock Vib. Dig., 7 (7), pp 97-106 (July 1975).

2. Bisplinghoff, R.L., Ashley, H., and Halfman, R.L., Aeroelasticity, Addison-Wesley (1955).

3. Jones, W.P., (Ed.), "Manual on Aeroelasticity," Part II, Aerodynamic Aspects, Advisory Group Aeronaut. Res. Dev. (1962).

Articles for the **Digest** will be reviewed for technical content and edited for style and format. Before an article is submitted, the topic area should be cleared with the editors of the **Digest.** Literature review topics are assigned on a first come basis. Topics should be narrow and well-defined. Articles should be 3000 to 4000 words in length. For additional information on topics and editorial policies, please contact:

Milda Z. Tamulionis
Research Editor
Vibration Institute
101 W. 55th Street, Suite 206
Clarendon Hills, Illinois 60514

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